Species Status Assessment Report for the Slenderclaw Crayfish (*Cambarus cracens*)

Version 1.4

Photo by Guenter Schuster

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U.S. Fish and Wildlife Service
Region 4
Atlanta, GA

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Suggested reference:

U.S. Fish and Wildlife Service. 2018. Species Status Assessment Report for the Slenderclaw Crayfish (*Cambarus cracens*), Version 1.4. April 2019. Atlanta, GA.

VERSION UPDATES

Version 1.0 (December 2017) to Version 1.1 (January 2018).

1) Version 1.1 incorporated expert comments on Chapter 2.
2) Developed evaluation criteria and added methods and results for current and future condition.
3) Inserted virile crayfish maps.
4) Write up on discovery analysis occupancy and detection probability models.
5) Updated information on life history of female form alteration.
6) Additions to literature cited.
7) Corrected grammatical errors.
8) Added discussion of survey information from Guntersville Lake.
9) Added that voucher specimens and documentation of species collection is important for identification purposes (low abundance section) and information was provided that a photo identification of slenderclaw crayfish was verified with voucher specimens.

Version 1.1 (January 2018) to Version 1.2 (February 2018). The changes between versions were minor and do not change the SSA analysis for the slenderclaw crayfish. The changes were:

1) Version 1.2 incorporated peer and partner reviewer and expert comments.
2) Clarified language and corrected grammatical errors.
3) Added the linear regression analysis and supplied R2 value to Figure 4-2 discovery analysis to provide visual of asymptote.
4) Provided more information on occupancy modeling and defined terms.
5) Updated literature cited.
6) Changed 'relative abundance' title of metric to 'abundance' title of metric, Table 4-3.
7) Included estimated rate of spread for virile crayfish from additional researcher.
8) Added location points to land use maps, Figures 4-4 and 4-5 and SLEUTH maps in Chapter 5.
9) Corrected Table 4-4; the 2016 Number of Positive Collections stated was 2 in Version 1.1 and corrected it to 0 in Version 1.2.

Version 1.2 (February 2018) to Version 1.3 (May 2018). The changes between versions were minor and do not change the SSA analysis for the slenderclaw crayfish. The changes were:

1) Updated life history information about crayfish egg development.
2) Clarified metric descriptions in future condition.
3) Added additional detail on survey methods and effort.
4) Added additional detail and citations in water quality section on metals.
5) Removed redundant information throughout the SSA report.
6) Made virile crayfish collection maps larger and moved to Chapter 3.
7) Provided further clarification on how overall current population resiliency was ranked.

Version 1.3 (May 2018) to Version 1.4 (April 2019). The changes between versions were minor and do not change the SSA analysis for the slenderclaw crayfish. The changes were:

1) Version 1.4 incorporated corrections based on public comments as appropriate.
2) Clarified that sediment is not a current concern where the slenderclaw crayfish occurs.
3) Added information and additional citations on virile crayfish invasion in West Virginia, Idaho, Wyoming, and Utah.
4) Grammatical edits.

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EXECUTIVE SUMMARY

This report summarizes the results of a Species Status Assessment completed for the slenderclaw crayfish (*Cambarus cracens*) to assess the species' overall viability. The slenderclaw crayfish is a relatively small, freshwater crustacean with a comparatively elongate, slender front claw (Bouchard and Hobbs 1976, p. 2). This species is a cryptic, stream-dwelling crayfish and is endemic to Sand Mountain in DeKalb and Marshall counties, Alabama on the Cumberland Plateau in the Tennessee River Basin.

To evaluate the viability of the slenderclaw crayfish, we characterized the needs, estimated the current condition, and predicted the future condition of the species' in terms of resiliency, representation, and redundancy (the 3Rs). Historically, the slenderclaw crayfish was collected at two sites in Marshall County (Shoal Creek and Short Creek) and three sites in DeKalb County (Scarham Creek and Bengis Creek). Currently, the species is found at three sites in Marshall County (Shoal Creek) and two sites in DeKalb County (Bengis Creek and Town Creek) (Figure ES-1). Two populations were delineated using Hydrologic Unit Code (HUC) 12 watershed boundaries and tributaries leading to the Tennessee River, which includes Short Creek mainstem and its tributaries and Town Creek mainstem and its tributaries.

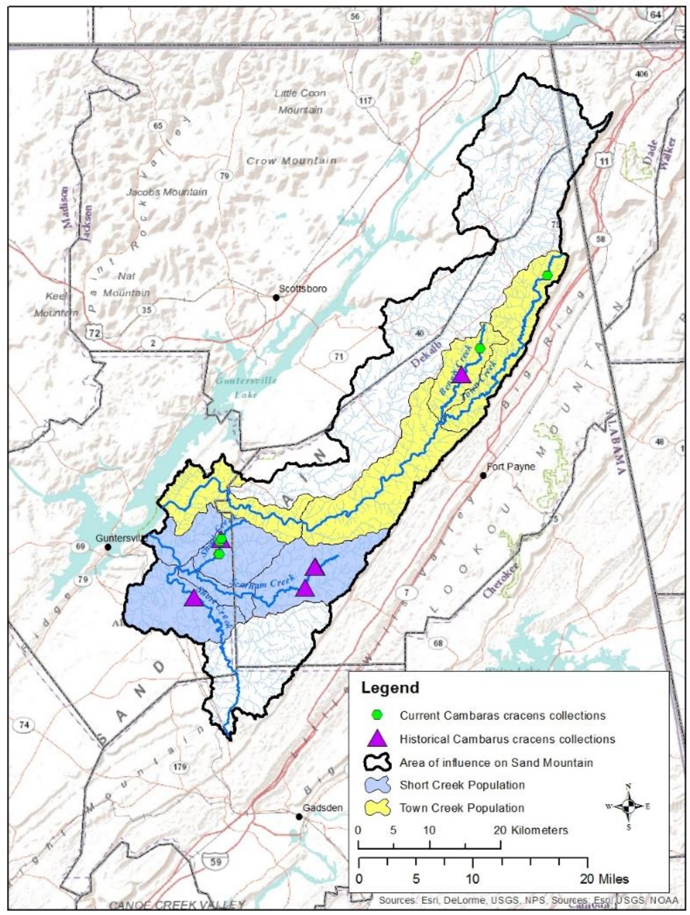

Figure ES-1. Slenderclaw crayfish (*Cambarus cracens*) populations based on HUC-12 watershed boundaries and tributaries flowing into Guntersville Lake on the Tennessee River. Sources: Bouchard and Hobbs 1976; Schuster 2017, unpublished data; Bearden et al. 2017; Kilburn et al. 2014.

The slenderclaw crayfish needs small to medium flowing streams (typically 20 feet wide or smaller and depths of 2.3 feet or shallower) with the attributes of predominately large boulders and fractured bedrock and no turbidity in sites from one population and streams dominated by small substrate types with a mix of sand, gravel, and cobble and no turbidity in sites from the second population. In addition, the species needs abundant interstitial space within each habitat type and adequate seasonal water flows to maintain benthic habitats and maintain connectivity of streams.

We considered hydrologic alteration (including water quantity), land-use change (poultry farming and agriculture), water quality, low abundance, the non-native virile crayfish (*Faxonius virilis*), and conservation efforts as factors influencing the viability of the slenderclaw crayfish. Briefly, the non-native virile crayfish has been identified as one of the primary threats to the slenderclaw crayfish, and it has been documented in Guntersville Lake, the type locality for slenderclaw crayfish, and other sites within the range of the slenderclaw crayfish. In addition, small population size (few numbers of collections despite survey efforts) puts slenderclaw crayfish at greater risk of extirpation from stochastic events. The current few number of individuals (n = 32) as evidenced by low capture rates, scientific collection and genetic drift are likely to negatively affect populations of the slenderclaw crayfish.

Each population (Short Creek and Town Creek) of the slenderclaw crayfish needs to be able to withstand, or be *resilient* to, stochastic events or disturbances (e.g. drought, major storms and flooding, accidental discharge of pollutants into streams, or fluctuations in reproduction rates). To be resilient, these populations need to have an adequate number of individuals, cover a large enough area (multiple sites within a population) that a localized event does not eliminate a population, and have connectivity among sites within a population such that areas could be repopulated if local site extirpations were to occur. We determined the factors of low abundance, non-native virile crayfish invasion, and water quality as affecting the current condition of slenderclaw crayfish and carried these forward into our current condition analyses. To assess current population resiliency of slenderclaw crayfish, we used abundance, evidence of reproduction, presence of virile crayfish, and water quality condition by population. To summarize the overall current population resiliency of the slenderclaw crayfish, we ranked the slenderclaw crayfish populations into a current condition category (High, Moderate, Low, and Very Low) based on the demographic and habitat factors outlined above. The slenderclaw crayfish resiliency analysis resulted in low overall condition for both Short and Town creek populations (Table ES-1).

Representation reflects a species' adaptive capacity to changing environmental conditions over time and can be characterized by genetic and ecological diversity within and among populations. For the slenderclaw crayfish, we used two metrics to assess representation: 1) habitat variability and 2) morphological variability. For the slenderclaw crayfish to exhibit adequate representation, resilient populations should occur in the two slightly different habitat types across the historical range. In addition, resilient populations should maintain individuals with minor morphological differences (found at the type locality). To maintain existing adaptive capacity, it is important to have resilient populations with sites in each population in the two habitat types and individuals in each population with morphological variations. At present, the slenderclaw crayfish has two populations in low condition (resiliency) with habitat types that vary between populations, but the morphological variation has been lost due to presumed extirpation at the type locality. Therefore, the species has some level of adaptive capacity, but given the low resiliency of both populations of the slenderclaw crayfish, current representation is reduced.

The metric of redundancy reflects a species' ability to remain extant after experiencing extreme catastrophic events. Redundancy for the slenderclaw crayfish is characterized by having multiple resilient populations and occupied sites distributed throughout its range. These populations should also maintain natural levels of connectivity between them; currently, the Town Creek population is separated from the Short Creek population due to Guntersville Lake resulting in reduced connectivity. The slenderclaw crayfish exhibits low natural redundancy given its narrow range. Currently, there are two populations spread throughout the species' historical range with three extirpated historical sites in the Short Creek population and one extirpated historical site in the Town Creek population, and thus the slenderclaw crayfish has limited redundancy. In addition, the currently occupied sites in the Short Creek population are in a single tributary, and one catastrophic event could impact the entire population.

To assess the future condition of the slenderclaw crayfish, we forecasted what the slenderclaw crayfish may have in terms of the 3Rs under three plausible future scenarios. Hydrologic alteration (precipitation change), land-use change, and non-native virile crayfish were the factors identified as affecting slenderclaw crayfish in the future. Therefore, we projected how these factors would change over time in order to develop our future scenarios to assess abundance, presence of non-native virile crayfish, and water quality condition by population at three time periods: 2020, 2030, and 2040. To summarize the overall population resiliency of the slenderclaw crayfish in the future, we ranked the slenderclaw crayfish populations into a condition category (High, Moderate, Low, Very Low, and Extirpated) based on the demographic and habitat factors outlined above.

In the future, the presence of virile crayfish is expected to reduce the 3Rs further. By the year 2040 and under Scenarios 1 and 2, the slenderclaw crayfish may persist, but this is with only one population (Town Creek) with low and very low resiliency, respectively; the Short Creek population is expected to become extirpated (Table ES-1). In Scenario 3, both populations of the slenderclaw crayfish is expected to be extirpated by 2040. The Short Creek population occurs in the large boulder, wider stream habitat type, and therefore, this habitat type will be lost, reducing the habitat variability of the slenderclaw crayfish. In addition, the morphological variation of the species occurred in the Short Creek population. Overall, there will be a reduction in the occupied range of the species through the loss of the Short Creek population, and at a minimum, its range within the Town Creek population will be highly restricted to the headwaters due to the expansion of virile crayfish and urban areas. Therefore, future representation of this species is reduced under all scenarios and time periods. In addition, the slenderclaw crayfish exhibits low natural redundancy given its narrow range, and in the future, the presence of virile crayfish is expected to reduce redundancy further. Within both populations of the slenderclaw crayfish, there are historical sites that are currently considered extirpated; in the future, additional sites (and possibly both populations) are expected to become extirpated. The recolonization of sites (or one of the populations) following a catastrophic event would be very difficult given the loss of additional sites (and one or both populations) and reduced available habitat to the remaining population due to virile crayfish expansion, urban growth, and Guntersville Lake.

Table ES-1. Summary of current and future resiliency of the slenderclaw crayfish (*Cambarus cracens*) populations, Short Creek and Town Creek. Time periods of 2020, 2030, and 2040 were used for the three future scenarios.

Population	Time Period	Current	Scenario 1	Scenario 2	Scenario 3
Short Creek	Current	Low			
	2020		Low	Low	Very Low
	2030		Extirpated	Low	Extirpated
	2040		Extirpated	Extirpated	Extirpated
Town Creek	Current	Low			
	2020		Low	Low	Low
	2030		Low	Low	Very Low
	2040		Very Low	Low	Extirpated

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CHAPTER 1 - INTRODUCTION

The slenderclaw crayfish (*Cambarus cracens*) is a freshwater crustacean found in tributaries to Guntersville Lake on the Tennessee River in DeKalb and Marshall counties, Alabama. On April 20, 2010, the U.S. Fish and Wildlife Service (Service) received a petition from the Center for Biological Diversity (CBD), the Alabama Rivers Alliance, the Clinch Coalition, Dogwood Alliance, the Gulf Restoration Network, Tennessee Forests Council, and the West Virginia Highlands Conservancy to list 404 aquatic, riparian, and wetland species, including the slenderclaw crayfish as endangered or threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543) (Act) and designate critical habitat (CBD 2010, entire). On September 27, 2011, we published a 90-day finding, which determined that the petition contained substantial information indicating the slenderclaw crayfish may warrant listing, and initiated a status review for the species (76 FR 59836). As a result of the Service's 2014 settlement with CBD, the Service is required to submit a 12-month finding to the *Federal Register* by September 30, 2018. Therefore, a review of the status of the species was initiated to determine if the petitioned action is warranted. Based on the status review, the Service will issue a 12-month finding for the slenderclaw crayfish. Thus, we conducted a Species Status Assessment (SSA) to compile the best available data regarding the species' biology and factors that influence the species' viability. The slenderclaw crayfish SSA Report is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA Report documents the results of the comprehensive status review for the slenderclaw crayfish and will be the biological underpinning of the Service's forthcoming decision on whether the species warrants protection under the Act.

The SSA framework (USFWS 2016, entire) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available, and to support all functions of the Ecological Services Program of the Service, from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification decisions (the former four decision types are only relevant should the species warrant listing under the Act). Therefore, we have developed this SSA Report to summarize the most relevant information regarding life history, biology, and considerations of current and future risk factors facing the slenderclaw crayfish. In addition, we forecasted the possible response of the species to various future risk factors and environmental conditions to formulate a complete risk profile for the slenderclaw crayfish.

The objective of this SSA is to thoroughly describe the viability of the slenderclaw crayfish based on the best scientific and commercial information available. Through this description, we determined what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios. In conducting this analysis, we took into consideration the likely changes that are happening in the environment – past, current, and future – to help us understand what factors drive the viability of the species.

For the purpose of this assessment, we define **viability** as the ability of the slenderclaw crayfish to sustain populations in natural river systems over time (at least 20 years based on future scenarios – Chapter 5). Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (USFWS 2016, p. 9). Using the SSA framework (Figure 1-1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its **resiliency**, **redundancy**, and **representation** (USFWS 2016, entire; Wolf et al. 2015, entire).

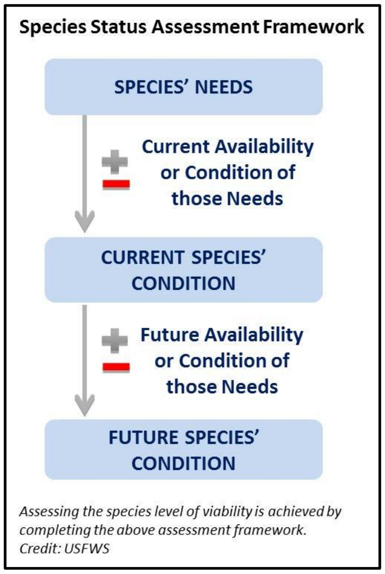

Figure 1-1. Species Status Assessment Framework.

• **Resiliency** describes the ability of a population to withstand stochastic disturbance. Stochastic events are those arising from random factors such as weather, flooding, or fluctuations in birth rates. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally speaking, populations need enough individuals, within habitat patches of adequate area and quality, to maintain survival and reproduction in spite of disturbance. Resiliency is measured using metrics that describe population condition and habitat; in the case of the slenderclaw crayfish, we used abundance, evidence of reproduction, presence of virile crayfish (*Faxonius virilis*), and water quality condition to assess resiliency.

• **Representation** describes the ability of a species to adapt to changing environmental conditions over time. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. Theoretically, the more representation the species has, the higher its potential of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluated representation based on the extent and variability of morphology and habitat characteristics across the geographical range for the slenderclaw crayfish.

• **Redundancy** describes the ability of a species to withstand catastrophic events. A catastrophic event is defined as a rare, destructive event or episode involving multiple sites (or populations) that occurs suddenly. Redundancy is about spreading the risk among populations, and thus, is assessed by characterizing the number of resilient populations across the range of the species. The more resilient populations the species has, distributed over a larger area, the better chances that the species can withstand catastrophic events. For the slenderclaw crayfish, we used the number of resilient populations, and the geographic distribution of those populations, to measure redundancy.

To evaluate the viability of the slenderclaw crayfish, we estimated and predicted the current and future condition of the species in terms of resiliency, redundancy, and representation.

This SSA Report includes the following chapters:

1. Introduction;
2. Species Biology, Individual Needs, and Defining Populations. The life history of the species and resource needs of individuals, historical and current range and distribution, and populations;
3. Factors Influencing Viability. A description of likely causal mechanisms, and their relative degree of impact, on the status of the species;
4. Species Needs and Current Condition. A description of what the species needs across its range for viability, and estimates of the species' current range and condition; and,
5. Future Conditions and Viability. Descriptions of plausible future scenarios, and predictions of their influence, on slenderclaw crayfish resiliency, representation, and redundancy.

This SSA Report provides a thorough assessment of the biology and natural history of the slenderclaw crayfish and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for the species. Importantly, this SSA Report does not result in, nor predetermine, any decisions by the Service under the Act. In the case of the slenderclaw crayfish, this SSA Report does not determine whether the slenderclaw crayfish warrants protections of the Act, or whether it should be proposed for listing as a threatened or endangered species under the Act. That decision will be made by the Service after reviewing this document, along with the supporting analysis, any other relevant scientific information, and all applicable laws, regulations, and policies. The results of the decision will be announced in the *Federal Register*. The contents of this SSA Report provide an objective, scientific review of the available information related to the biological status of the slenderclaw crayfish.

CHAPTER 2 - SPECIES BIOLOGY, INDIVIDUAL NEEDS, AND DEFINING POPULATIONS

In this chapter, we provide biological information about the slenderclaw crayfish, including its taxonomic history, morphological description, and known life history. We then outline the resource needs of individuals. Lastly, we review the information on the current and historical range and distribution of the species, and then define populations.

2.1 Taxonomy

Originally, the slenderclaw crayfish was described as the sole member of the subgenus *Exilicambarus*, and therefore named *Cambarus* (*Exilicambarus*) *cracens* (Bouchard and Hobbs 1976, p. 2). The slenderclaw crayfish was described from collections from Short Creek at State Route 75, 1.1 miles southwest of the junction with State Route 68, Marshall County, Alabama (Bouchard and Hobbs 1976, p. 7). Recently, based on the absence of phylogenetic validity, the subgenus *Exilicambarus* was eliminated along with all other subgeneric classifications in the genus *Cambarus* (Crandall and De Grave 2017, p. 5). The slenderclaw crayfish, *Cambarus cracens*, is currently recognized as a valid taxon (Owen et al. 2015, p. 4; Taylor et al. 2007, p. 382). The currently accepted classification of the slenderclaw crayfish is:

Phylum: Arthropoda
Class: Crustacea
Order: Decapoda
Infraorder: Astacidea
Superfamily: Astacoidea
Family: Cambaridae
Genus: *Cambarus*
Species: *Cambarus cracens*

2.2. Species Description

The slenderclaw crayfish is a relatively small, freshwater crustacean with a comparatively elongate, slender front claw (chela) (Figure 2-1; Bouchard and Hobbs 1976, p. 2). This species is a cryptic, stream-dwelling crayfish and is considered a tertiary burrower (R. Bearden pers. comm. 2017). The largest individual collected was a female with a carapace length of 1.56 inches (in) (39.7 millimeters (mm)) (Bouchard and Hobbs 1976, p. 7). First form males have ranged from 1.09 in (27.7 mm) to 1.47 in (37.3 mm) carapace length (Bouchard and Hobbs 1976,

Figure 2-1. Adult slenderclaw crayfish (*Cambarus cracens*). Photo by Guenter Schuster.

p. 8). The areolas are 3.4 times as long as they are broad and have six widely spaced pore-like punctations across at the narrowest part.

Variations have been noted in the morphology and color of the slenderclaw crayfish. The spination of the carapace was more pronounced in most of the individuals collected at the type locality when compared to individuals collected from other sites (Bouchard and Hobbs 1976, p. 7). Also, the marginal spines on the rostrum were reduced in most of the individuals collected outside of the type locality (Bouchard and Hobbs 1976, p.7). Two color forms have been documented from one site. The first color form documented has a mostly uniform olive green to rusty brown on the carapace (Schuster et al. 2017, p. 97). The second color variation has a distinct mottled pattern, and the basal color of the carapace is light gray to straw colored and overlain with speckling of rusty red to dark brown (G. Schuster pers. comm. 2017; Schuster et al. 2017, p. 97).

2.3 Life History

Except for its original description (Bouchard and Hobbs 1976, entire), very little is known of the biology and life history of the slenderclaw crayfish. Therefore, the following description is based primarily on information for the family Cambaridae and historical and current collections of the slenderclaw crayfish. The species has four identified life stages: fertilized eggs, juveniles, non-breeding adults, and breeding adults (Figure 2-2).

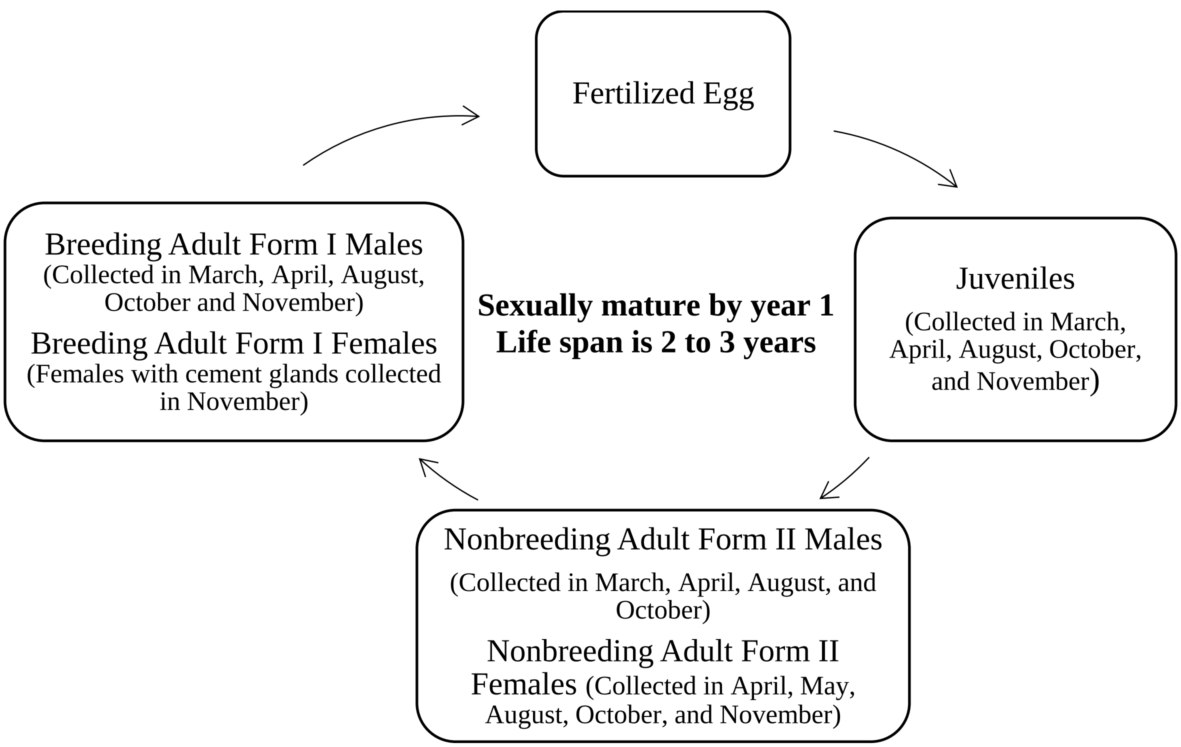

Figure 2-2. Slenderclaw crayfish life stages based on historical and current collections and general crayfish biology (Bouchard and Hobbs 1976; Bearden et al. 2017; Schuster et al. 2017).

In the southern United States, cambarid crayfish generally mate in the spring and extrude eggs in the fall (Taylor et al. 1996, p. 27). An ovigerous (egg-bearing) female is referred to as being “in berry.” Female crayfish generally carry eggs on the underside of their abdomen for several weeks before hatching (Mclay et al. 2016, p. 99). The eggs are attached to the abdomen by glair that is produced by cement glands (or glair glands). The female fans the eggs to keep them oxygenated and free of sediment (G. Schuster pers. comm. 2017). During this time, the female is vulnerable and takes shelter for protection, because she is unable to flip her tail to swim away while the eggs are on her abdomen (G. Schuster pers. comm. 2017).

After hatching, juveniles remain on the underside of the female’s abdomen for several weeks to potentially several months (Jurcak et al. 2016, p. 100). Juvenile slenderclaw crayfish have been collected in March, April, August, October, and November suggesting that this species has a prolonged spawning window and the release of eggs is likely flexible depending on environmental conditions (Table 2-1; C. Taylor pers. comm. 2017).

In order to grow, crayfish must shed and separate from their exoskeleton and grow a new one through a process called molting. After molting, the crayfish is unable to move effectively and has a soft body, and is therefore vulnerable during this time. Like other cambarid crayfishes, adult slenderclaw crayfish have two forms: Form I, which is reproductively active (breeding), and Form II, which is reproductively inactive (non-breeding) (Figure 2-2). By molting, male crayfish undergo form alternation between Form I and Form II. Form I males have been collected in March, April, August, October, and November (Schuster et al. 2017, p. 97; Bouchard and Hobbs 1976, p. 7). Cambarid female crayfish also undergo form alternation by molting (Wetzel 2002, p. 326). Form I females have wider abdomens to accommodate the carrying of eggs and young and visible (swollen) white glair glands, while Form II females have narrower abdomens and no visible white glair glands (Wetzel 2002, pp. 328-331). No ovigerous slenderclaw crayfish females have been collected, though females with cement glands have been collected in November, an indication that their ovaries were mature at that time (Bouchard and Hobbs 1976, p. 8). Sexual maturity is believed to be reached by year one (G. Schuster pers. comm. 2017). The slenderclaw crayfish likely has a life span of two to three years (G. Schuster pers. comm. 2017).

Based on information from other crayfish species, slenderclaw crayfish likely feed upon aquatic macroinvertebrates in the juvenile stage and shift toward omnivory in the adult stage (G. Schuster pers. comm. 2017).

Table 2-1. Timing of captures of slenderclaw crayfish by life stage and sex. Sources: Bouchard and Hobbs 1976; Bearden et al. 2017; Schuster et al. 2017; Schuster 2017, unpublished data; Taylor 2017, unpublished data.

Life Stage	**Month**											
	Jan	**Feb***	**Mar***	**Apr***	**May***	**Jun***	**Jul***	**Aug***	**Sep**	**Oct***	**Nov***	**Dec**
Juveniles												
Form I Males												
Form I Females (With Cement Glands)												
Form II Males												
Form II Females												

*Survey months include February, March, April, May, June, July, August, October, and November.

2.4 Resource Needs (Habitat) of Individuals

Adult and juvenile slenderclaw crayfish are normally found in flowing water in streams, with intact riparian cover and boulder/cobble structure, and are found exclusively on Sand Mountain, DeKalb and Marshall counties, Alabama. Historical surveys of slenderclaw crayfish documented the habitat at the type locality, Short Creek, as a clear, slow flowing stream with bedrock and sandy substrate, and large rocks throughout (Bouchard and Hobbs 1976, p 8). Recent surveys have documented two slightly different habitat types. The first type of habitat is streams with predominantly large boulders and fractured bedrock, widths ranging from 16.4 feet (ft) – 19.7 ft (5 – 6 meters (m)), no turbidity, and depths up to 2.3 ft (0.7 m). The second type of habitat is streams with larger amounts of smaller substrate types with a mix of sand, gravel, and cobble, widths approximately 9.8 ft (3 m), no turbidity, and depths up to 0.5 ft (0.15 m) (R. Bearden pers. comm. 2017). During low stream flow periods, slenderclaw crayfish appear to use any available water, so during these low flow events, individuals have been found in pool habitats or near undercut banks. No individuals have been found in dry channels during sampling effort in low water conditions (R. Bearden pers. comm. 2017).

Table 2-2. Resource needs for slenderclaw crayfish to complete each life stage.

Life Stage	Resources needed	Information Source
Fertilized Eggs	• Female to carry eggs • Water to oxygenate eggs • Female to fan eggs to prevent sediment buildup and oxygenate water as needed • Female to shelter in boulder/cobble substrate and available interstitial space	R. Bearden pers. comm. 2017 S. McGregor pers. comm. 2017 G. Schuster pers. comm. 2017 C. Taylor pers. comm. 2017
Juveniles	• Female to carry juveniles in early stage • Water • Food – aquatic macroinvertebrates • Boulder/cobble substrate and available interstitial space for shelter	R. Bearden pers. comm. 2017 S. McGregor pers. comm. 2017 G. Schuster pers. comm. 2017 C. Taylor pers. comm. 2017
Adults	• Water • Food – omnivorous, opportunistic and generalist feeders • Boulder/cobble substrate and available interstitial space for shelter	Jurcak et al. 2016, p. 123 Taylor and Schuster 2004, p. 13 R. Bearden pers. comm. 2017 S. McGregor pers. comm. 2017 G. Schuster pers. comm. 2017 C. Taylor pers. comm. 2017

2.5 Range and Distribution

The slenderclaw crayfish is endemic to Sand Mountain in the Southwestern Appalachians Level III Ecoregion, on the Cumberland Plateau in the Tennessee River Basin. It is found in Alabama in tributaries on the south side of Guntersville Lake on the Tennessee River. The type locality is Short Creek, Marshall County, Alabama, where the species was described in 1976 (Bouchard and Hobbs 1976, p. 7). Historically, the slenderclaw crayfish was collected at two sites in Marshall County (Shoal Creek and Short Creek) and three sites in DeKalb County (Scarham Creek and Bengis Creek) (Figure 2-3).

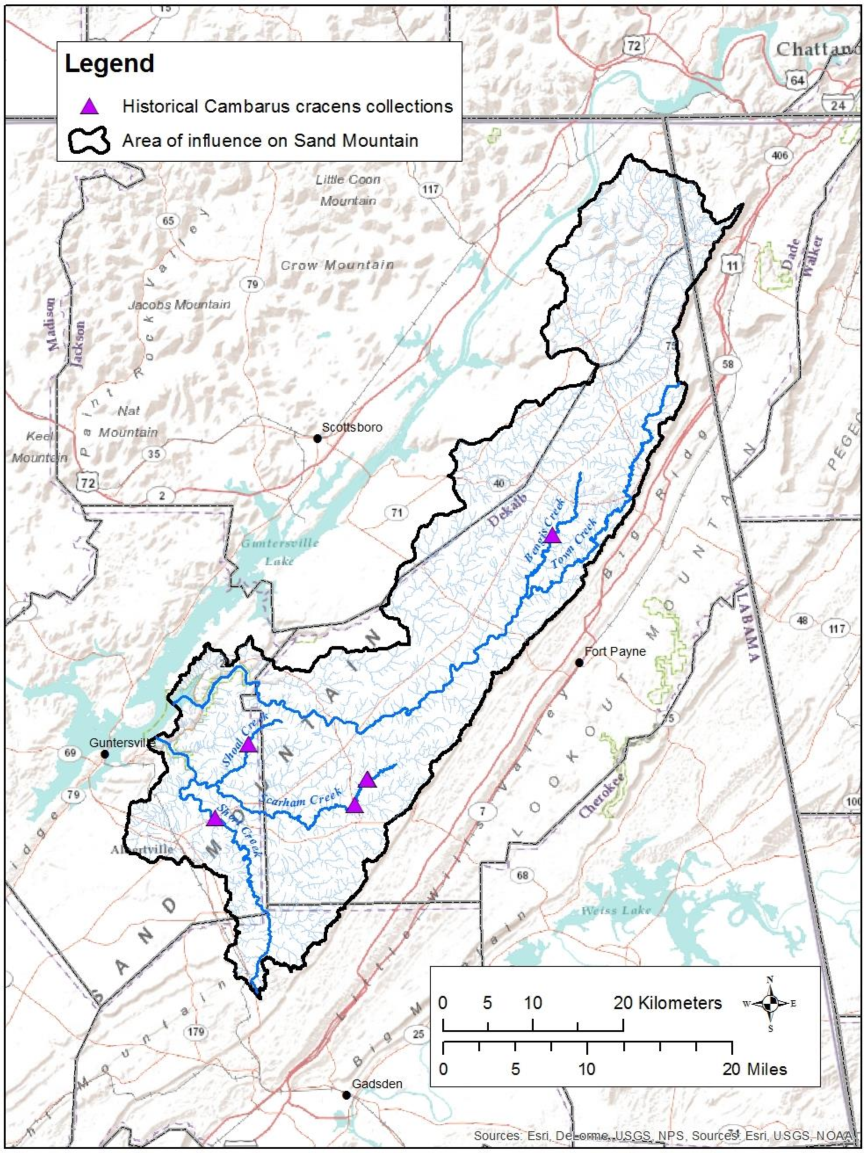

Figure 2-3. Slenderclaw crayfish historical range map on Sand Mountain in DeKalb and Marshall counties, Alabama. Purple triangles are historical collections of slenderclaw crayfish (1970 – 1974). Black outline is area of influence on Sand Mountain. Source: Bouchard and Hobbs 1976.

Currently, the species is found at three sites in Marshall County (Shoal Creek) and two sites in DeKalb County (Bengis Creek and Town Creek) (Figure 2-4). The area of influence was determined by the overall terrain and geology on Sand Mountain and used to help determine the factors influencing the viability of the slenderclaw crayfish.

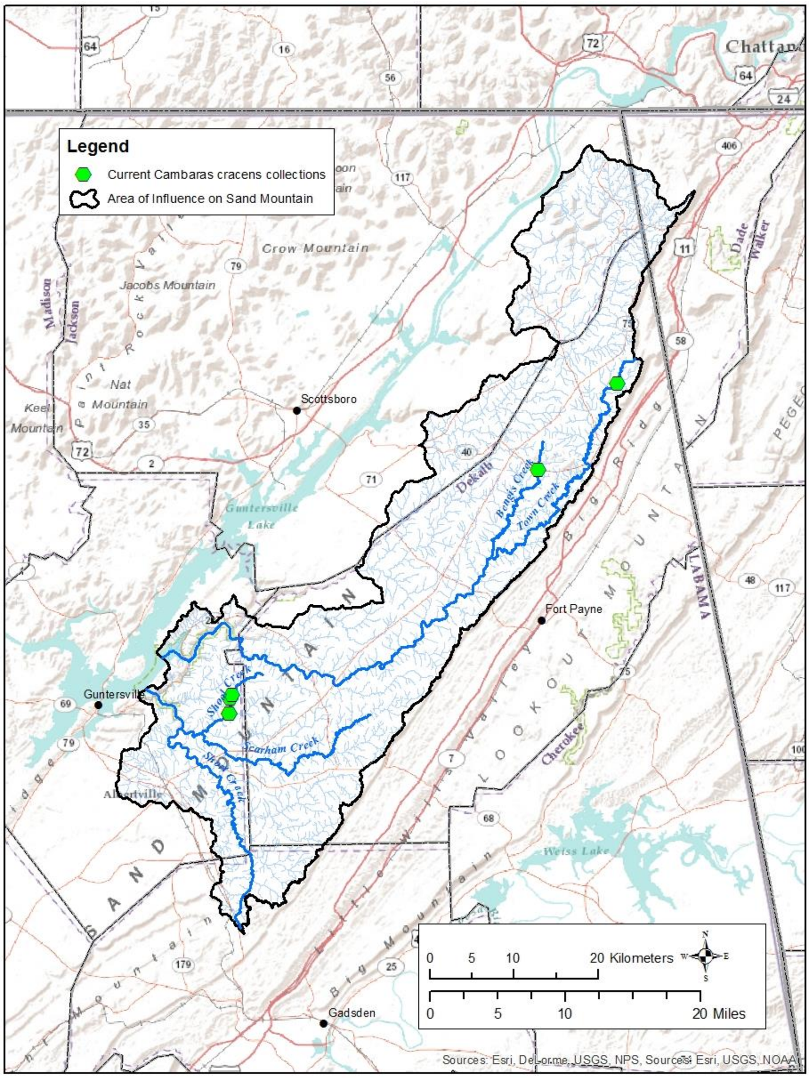

Figure 2-4. Slenderclaw crayfish current range map on Sand Mountain in DeKalb and Marshall counties, Alabama. Green circles are current collections of slenderclaw crayfish (2009 – 2017). Black outline is area of influence on Sand Mountain. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data; Bearden et al. 2017; Kilburn et al. 2014.

2.6 Populations

For the slenderclaw crayfish, two populations were delineated using Hydrologic Unit Code (HUC) 12 (U.S. Geological Survey) watershed boundaries and tributaries leading to the

Tennessee River (Figure 2-5) which includes Short Creek mainstem and its tributaries and Town Creek mainstem and its tributaries. In the Short Creek Population, the crayfish has been collected at six sites (one historical location on Short Creek, two historical locations on Scarham Creek, and three current locations on Shoal Creek). Within the Short Creek population, 90 slenderclaw crayfish, with 56 of those being juveniles, were collected from 1970-1974 (Table 2-3). In the Town Creek Population, the crayfish has been collected at three sites (one historical location on Bengis Creek, one current location on Bengis Creek, and one current location on Town Creek). Only one crayfish was historically collected in the Town Creek population (Table 2-3).

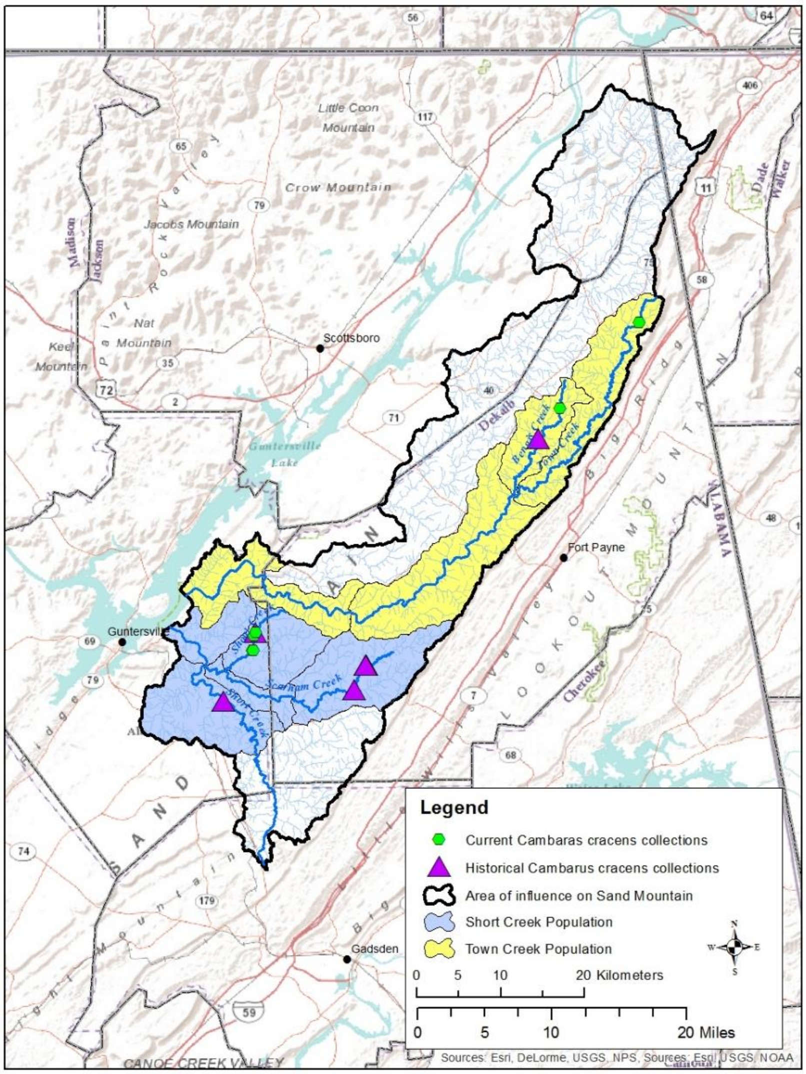

Figure 2-5. Slenderclaw crayfish populations based on HUC-12 watershed boundaries and tributaries flowing into Guntersville Lake on the Tennessee River. The Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow. Purple triangles are historical collections, and green circles are current collections. Sources: Bouchard and Hobbs 1976; Schuster 2017, unpublished data; Taylor 2017, unpublished data; Bearden et al. 2017; Kilburn et al. 2014.

Table 2-3. Abundance (total number collected) and evidence of reproduction for slenderclaw crayfish (*Cambarus cracens*) within Short and Town creek populations. Values are based on data collected from 1970 – 1974. Sources: Bouchard and Hobbs 1976.

Population	Number of Sites	Number of Positive Collections	Number of Adults	Number of Juveniles	Total Number Collected
Short	4	6	34	56	90
Town	1	1	1	0	1

2.6.1 Areas Presumed Extirpated

Within the Short Creek and Town Creek populations, multiple sites are no longer considered occupied by the slenderclaw crayfish. Three sites are now presumed extirpated in the Short Creek population and one site is presumed extirpated in the Town Creek population. Repeated survey efforts have attempted to collect the slenderclaw crayfish at the type locality on Short Creek and the other three historical sites on Scarham and Bengis creeks, but it has not been collected at these sites since the 1970s (see Section 4.1.1 Survey Efforts Summary for further information on surveys).

CHAPTER 3 – FACTORS INFLUENCING VIABILITY

The following discussion provides a summary of the factors that are affecting or could be affecting the current and future condition of the slenderclaw crayfish throughout some or all of its range.

3.1 Hydrologic Variation and Alteration

Sand Mountain streams are prone to low water conditions during the fall and early winter months before the winter wet season (USGS 2017). On Sand Mountain, the Pottsville aquifer is not a reliable source of large amounts of groundwater for recharge of these streams (Kopaska-Merkel, et al. 2008, p. 19). Therefore, this system is vulnerable to changes in hydrology and water availability. In addition to the seasonal low water conditions that are a natural part of the Sand Mountain streams system, there is a high number of small impoundments on Sand Mountain (M. Holley pers. comm. 2017) which may further alter the hydrology and available surface water in these streams. Over time, the slenderclaw crayfish may have become adapted to a seasonal cycle of low water conditions. In the future, if Sand Mountain streams have a further reduction in water availability due to hydrologic alteration (manmade = more impoundments or dams, or natural = decrease in precipitation), this could be a factor that negatively influences the viability of the slenderclaw crayfish since the crayfish is adapted to living in streams and has not been found in dry channels.

Dams and reservoirs on the Tennessee River have reduced connectivity for the slenderclaw crayfish by altering some of the habitat from a flowing stream to standing, impounded water. Completed in 1939, Guntersville Lake exists on the Tennessee River in the range of the slenderclaw crayfish (TVA 2018). Town Creek and Short Creek (two populations for the slenderclaw crayfish) drain into Guntersville Lake on the Tennessee River. Crayfish sampling has been conducted in Guntersville Lake and no slenderclaw crayfish have been found during these efforts (see Section 4.1, Figure 4-1 – survey effort). To date, the slenderclaw crayfish has not been documented in impounded areas, and the reservoir likely poses a barrier between the two populations and reduces the exchange of genetic material (Schuster 2017, unpublished data). It should be noted that slenderclaw crayfish was first collected in 1970 (approximately 31 years after the completion of Guntersville Lake), and therefore, the range of the slenderclaw crayfish prior to Guntersville Lake creation is unknown and the impacts of lake creation on the slenderclaw crayfish during that time are unknown.

3.2 Land-Use - Poultry Farming and Agriculture

Alabama is ranked third in the United States for broiler production (Alabama Poultry Producers 2017), and DeKalb and Marshall counties are two of the four most active counties in Alabama for poultry farming (Conner 2008). Within these counties, the amount of land area in farms (pastureland, poultry production, and row crop production) has shown a decreasing trend over time (Bearden et al. 2017, p. 27). Prior to the discovery of the slenderclaw crayfish, DeKalb and

Marshall counties total acreage in farms in 1969 was 60% (299,316 total acres) and 51% (205,105 total acres), respectively, which included pastureland, poultry production, and row crop production (USDA 1972, p. 285). By 2012, the total acreage in farms had decreased to 46% (229,294 total acres) and 41% (162,980 total acres) in DeKalb and Marshall counties (USDA 2014, pp. 230, 234). Though the amount of area in farm land has decreased since 1969, water quality has been documented to be impacted by these practices (Bearden et al. 2017, p. 18). Degradation of water quality impacts the food sources of slenderclaw crayfish and causes stress to individuals (Arthur et al. 1987, p. 328; Devi and Fingerman 1995, p. 749; Rosewarne et al. 2014, p. 69). In the future, it is not expected for land use to change drastically; however, an increase to more urban from agriculture and poultry farming on the landscape could potentially impact the slenderclaw crayfish. The expansion of urban areas may reduce available habitat where the slenderclaw crayfish occurs, as well as increase impervious surface and resultant runoff, which reduces the water quality the species may require.

One impact to the Sand Mountain landscape from poultry farming is the spreading of poultry litter, a mixture of chicken manure, feathers, spilled food, and bedding material that frequently is used to fertilize pastureland or row crops. A broiler house containing 20,000 birds will produce approximately 150 tons of litter a year (Ritz and Merka 2013, p. 2). Surface-spreading of litter allows runoff from heavy rains to carry nutrients from manure into nearby streams. Repeated or over application of poultry litter can result in phosphorus buildup in the soil (Sharpley et al. 2007, p. 383). Excess phosphorus and nitrogen in stream systems increases blue-green algae and undesirable aquatic plants that remove oxygen from the water, causing fish kills. Litter can also contain arsenic, which is formed from a chemical routinely used as a feed additive to prevent disease and stimulate growth (Stolz et al. 2007, p. 821). Other substances often found in poultry litter included fecal coliform, salmonella, and other pathogens, pesticide residue, and other heavy metals (Bolan et al. 2010, pp. 676, 683). Impacts from poultry litter spreading to water quality are further discussed below in Section 3.3 Water Quality.

3.3 Water Quality

Within the range of the slenderclaw crayfish, pollution from nonpoint sources stemming from agriculture, animal production, and runoff from unimproved roads has been documented (Bearden et al. 2017, p. 18). On Sand Mountain, the soils are highly erodible and carry nutrients and pollutants into the streams. The Alabama Department of Environmental Management (ADEM) identified Scarham Creek and Town Creek as impaired waters, and these waterways were listed on Alabama's 303(d) list in 1996 and 1998, respectively (ADEM 1996, p. 1 and 2001, p. 11). Scarham Creek was placed on the 303(d) for impacts from pesticides, siltation, ammonia, low dissolved oxygen/organic enrichment, and pathogens from agricultural sources (ADEM 2013, p. 1). Scarham Creek was removed from Alabama's 303(d) list of impaired waters in 2004 (ADEM 2006, entire; See Section 3.6 Conservation Benefits) after the Total Maximum Daily Loads (TMDLs) were developed in 2002 (ADEM 2002, p. 5). Town Creek was previously listed on the 303(d) list for ammonia and organic enrichment/dissolved oxygen impairments and TMDLs have been development for these issues (ADEM 1996, entire). Town Creek is currently on the 303(d) list for mercury contamination due to atmospheric deposition (ADEM 2016a, p. Appendix C).

Poultry farms and poultry litter have been documented to contain nutrients, pesticides, bacteria, heavy metals, and other pathogens (Bolan et al. 2010, pp. 676-683; Stolz et al. 2007, p. 821) which have the potential to pollute streams. Poultry litter spreading occurs within the Short Creek population (TARCOG 2015, p. 8). Within the range of the slenderclaw crayfish, ammonia concentrations were reflective of nonpoint source pollution at low flow and high flow measurements (Bearden et al. 2017, p. 21). Though crayfish generally have a higher tolerance to ammonia than some aquatic species such as mussels, their likely food source of larval insects is impacted by ammonia at lower concentrations (Arthur et al. 1987, p. 328). Juvenile slenderclaw crayfish likely feed exclusively on aquatic macroinvertebrates, and therefore, elevated ammonia levels may impact the crayfish's food source. Ammonia toxicity studies have not been conducted specifically for the slenderclaw crayfish. Other pollutants from poultry farming and litter are *E. coli* and the nutrients nitrogen and phosphorus. Excessive nutrients in waterways can cause excessive algal growth which in turn reduces or eliminates oxygen in the water and lowers water quality (EPA 2018a). At this time, the impacts of excessive nutrients on the slenderclaw crayfish are unknown.

Elevated levels of heavy metals, including zinc, lead, and mercury, are also documented in the range of the slenderclaw crayfish (Bearden et al. 2017, p. 22; ADEM 2016a, p. Appendix C). These heavy metals are known to have negative effects to aquatic life (USFWS 1987, p. 34; USFWS 1988, p. 44; USFWS 1993, p. 75). Crayfish densities have been shown to be limited by metal concentrations that exceed the chronic water quality criteria (Allert et al. 2008, p. 105). Mercury is currently listed as a pollutant in Town Creek (ADEM 2016a, p. Appendix C). This contaminant, as well as cadmium and lead, are known to be neurotoxins in fish, wildlife, and humans and are documented to impact enzyme activity in the central nervous system of crayfish (Devi and Fingerman 1995, p. 749). In general, the input of these compounds into rivers and streams can diminish water quality, thus at a minimum, impact the probable food source of the slenderclaw crayfish.

Increased amounts of sedimentation is understood to have negative effects on aquatic species (Newcombe and MacDonald 1991, p.72; Burkhead et al. 1997, p. 411; Burkhead and Jelks 2001, p. 964). Sedimentation can affect aquatic species, such as fish, by degrading physical habitat used for foraging, sheltering and spawning (Burkhead and Jelks 2001, p. 964; Sutherland 2005, p. 90), altering food webs and stream productivity (Schofield et al. 2004, p. 907), forcing altered behaviors (Sweka and Hartman 2003, p. 346), and even having sub-lethal effects and mortality on individual fish (Sutherland 2005, p. 94; Wenger and Freeman 2007, p. 7). Excess suspended sediment limits oxygen uptake capacity in crayfish whose gills are heavily fouled with particles (Rosewarne et al. 2014, p. 69). Increased sediment in the system may impact the slenderclaw crayfish in the form of reduced oxygen uptake, reduced interstitial spaces used for shelter, altered predator-prey interactions, and altered food webs. Sedimentation has not been identified as a concern where slenderclaw crayfish currently occurs, but the highly erodible soils in the surrounding area and siltation documented in Scarham Creek (ADEM 2013, p. 1) makes these systems susceptible to lower water quality conditions.

3.4 Low Abundance

Many populations are extirpated or reduced due to deterministic factors like habitat loss, overexploitation, and climate change. However, even when the habitat and conditions are favorable, populations may become extinct as a result of various stochastic events and natural catastrophes. Random events like drought, floods, and fires exacerbate each other and become more likely to cause extirpation or extinction in small populations (Shaffer 1981, p. 131). In general, the fewer populations a species has or the smaller its population size, the greater the likelihood of extinction by chance alone (Shaffer and Stein 2000, p. 307). Small population size (few numbers of collections despite survey efforts; see Section 4.1 Survey Efforts) puts slenderclaw crayfish at greater risk of extirpation from stochastic events. In addition, there are only two populations (as outlined in Section 2.6) with limited connectivity between populations which may have reduced genetic diversity. Genetic drift occurs in all species, but is more likely to negatively affect populations that have a smaller effective population size (Caughley 1994, pp. 219-220; Huey et al. 2013, p. 10).

Because of the difficulty in identifying the slenderclaw crayfish in the field, researchers have historically collected individuals for later identification, resulting in removal of individuals from the populations. These vouchered specimens are important for identification and documentation purposes of the slenderclaw crayfish. At this time, researchers do not believe collection of the slenderclaw crayfish for scientific purposes has impacted populations. However, if collection is removing breeding adults from the population, then the effects on the population could be unsustainable and the individual populations may decline. With the current few number of individuals (n = 32) (i.e. small population size) as evidenced by low capture rates, collection – and particularly repeated collection (e.g. in multiple subsequent years) – could further deplete the number of breeding adults. This may result in collapse of reproduction (or extirpation) at a site and cause a decline of resiliency for the populations.

3.5 Non-Native Species

The virile crayfish (*Faxonius virilis*), previously recognized as *Orconectes virilis* (Crandall and De Grave 2017, p. 5), is a crayfish native to the Missouri, upper Mississippi, lower Ohio, and the Great Lakes drainages (USFWS 2015, p. 1). The species has spread from its native range through dispersal as fishing bait, as pets, and through commercial (human) consumption (Schwartz et al. 1963, p. 267; USFWS 2015, p. 4,). Virile crayfish is a relatively tolerant species, inhabiting a variety of watersheds in the United States, including those with very few to no native crayfish species (Larson et al. 2010, p. 2). Virile crayfish are generalists and able to withstand various conditions and have been documented in lake, wetland, and stream environments and have the natural tendency to migrate (Loughman and Simon 2011, p. 50). This species has been documented to spread approximately 124 miles (200 km) over 15 years (B. Williams pers. comm. 2018; Williams et al. 2011, entire).

The virile crayfish has been documented in Guntersville Lake, at the slenderclaw crayfish type locality in Short Creek, and other sites within the range of slenderclaw crayfish (Schuster 2017, unpublished data; Taylor 2017, unpublished data). Virile crayfish were first collected near the range of slenderclaw crayfish in 1967 (Figure 3-1; Schuster 2017, unpublished data). Over time, virile crayfish have spread in a northeasterly direction and are now found within the known range of slenderclaw crayfish (Figure 3-1; Schuster 2017, unpublished data; Taylor 2017, unpublished data).

The specifics of how virile crayfish affects slenderclaw crayfish are to be determined; though body size, average chelae size, aggression levels, and growth rates have indicated that virile crayfish has an ecological advantage compared to several native crayfish species, including those in the *Cambarus* and *Procambarus* genera (Hale et al. 2016, p. 6). Virile crayfish have been documented to displace native crayfish (Hubert 2010, p. 5). Research on the spinycheek crayfish (*Faxonius limosus*), previously recognized as *Orconectes limosus* (Crandall and De Grave 2017, p. 5), indicates that this native species has been extirpated in West Virginia following the invasion of the virile crayfish, and the Potomac River draining in West Virginia, a drainage where native crayfish were previously found, is currently only occupied by virile crayfish (Loughman and Welsh 2010, p. 70 and 72). In the Snake River drainage and Bonneville Basin of southeastern Idaho, western Wyoming, and northern Utah, the introduced virile crayfish may pose a threat to native species. Of 22 sites sampled, with 12 being historical locations for native crayfishes, 21 sites documented no recent captures of two native crayfish species (Larson et al. 2018, p. 180). However, because the virile crayfish has been replaced by the invasive rusty crayfish (*Faxonius rusticus*) (previously recognized as *Orconectes rusticus*) (Crandall and De Grave 2017, p. 5), in its own native range, more research on dynamics of crayfish should be done to determine what causes one species to outcompete another in a non-native habitat (Hale et al. 2016, p. 7).

The virile crayfish is known to alter and reduce macrophyte biomass and diversity. The adaptive nature of virile crayfish, the effects of the species on other crayfish species in their native ranges, and records of its presence in slenderclaw crayfish’s historical range indicate that virile crayfish is a factor that may negatively influence the viability of the slenderclaw crayfish in the near-term and future. Also, considering that the virile crayfish is a larger crayfish, a strong competitor, and tends to migrate, while the slenderclaw crayfish has low abundance and is a smaller-bodied crayfish, it is reasonable to infer that once virile crayfish is established at a site it will out-compete slenderclaw crayfish. This may already be the case at the slenderclaw crayfish type locality where virile crayfish were found in surveys conducted from 2009 – 2017.

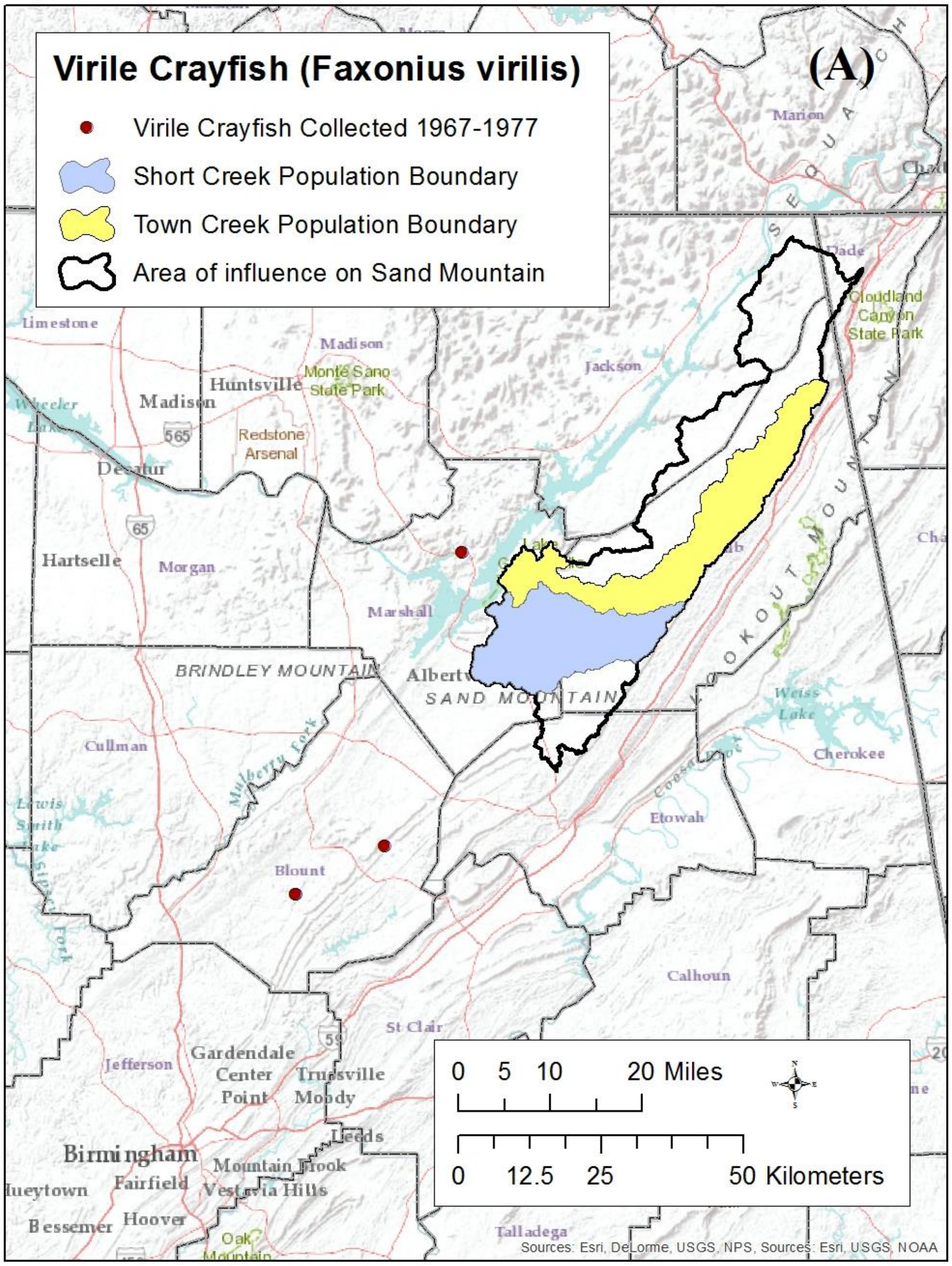

Figure 3-1A. Documented presence of virile crayfish within the historical range and surrounding area of slenderclaw crayfish during 1967 – 1977. Slenderclaw crayfish area of influence is outlined in black. Red circles are locations where virile crayfish were collected. Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data.

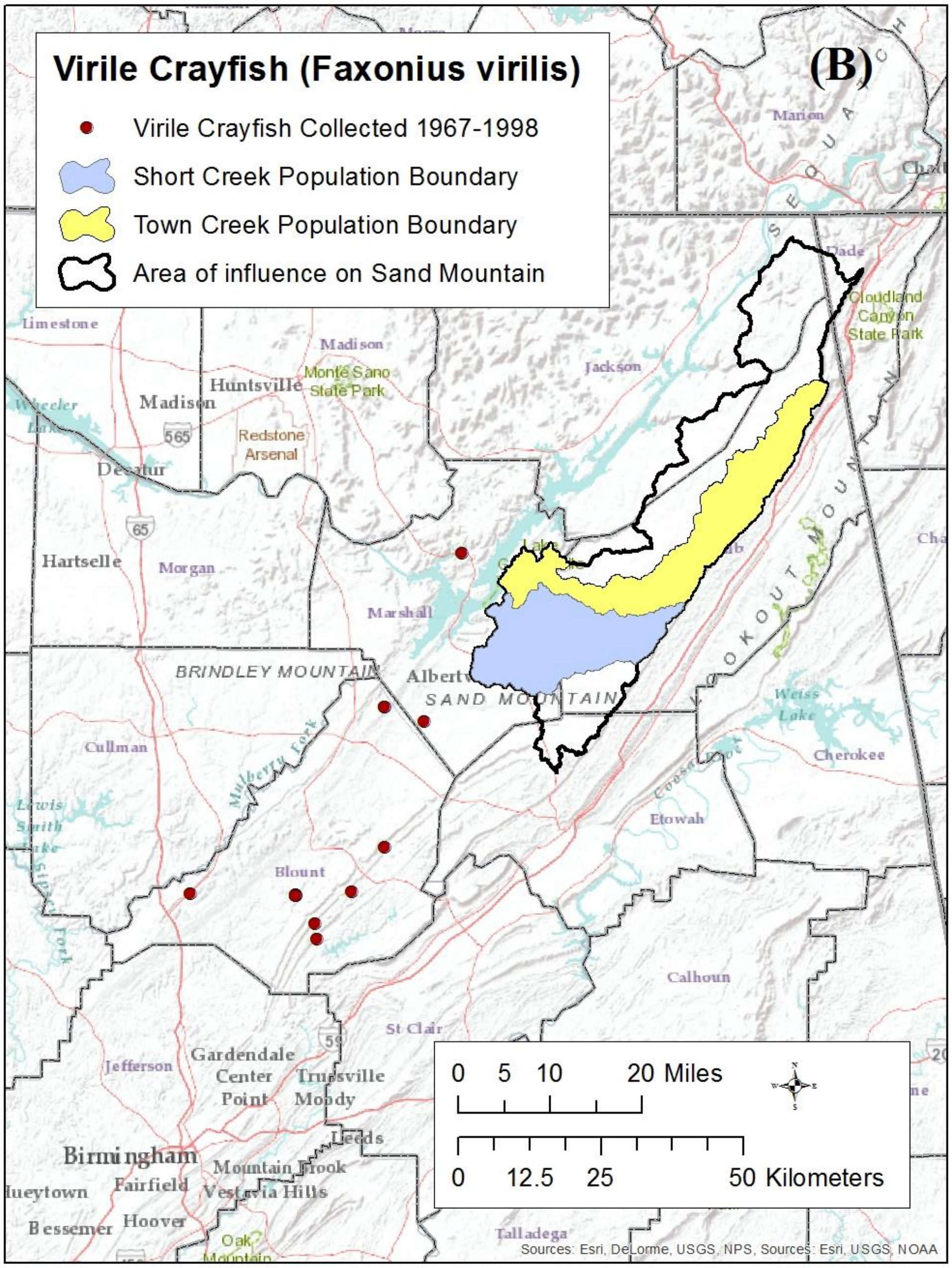

Figure 3-1B. Documented presence of virile crayfish within the historical range and surrounding area of slenderclaw crayfish during 1967 – 1998. Slenderclaw crayfish area of influence is outlined in black. Red circles are locations where virile crayfish were collected. Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data.

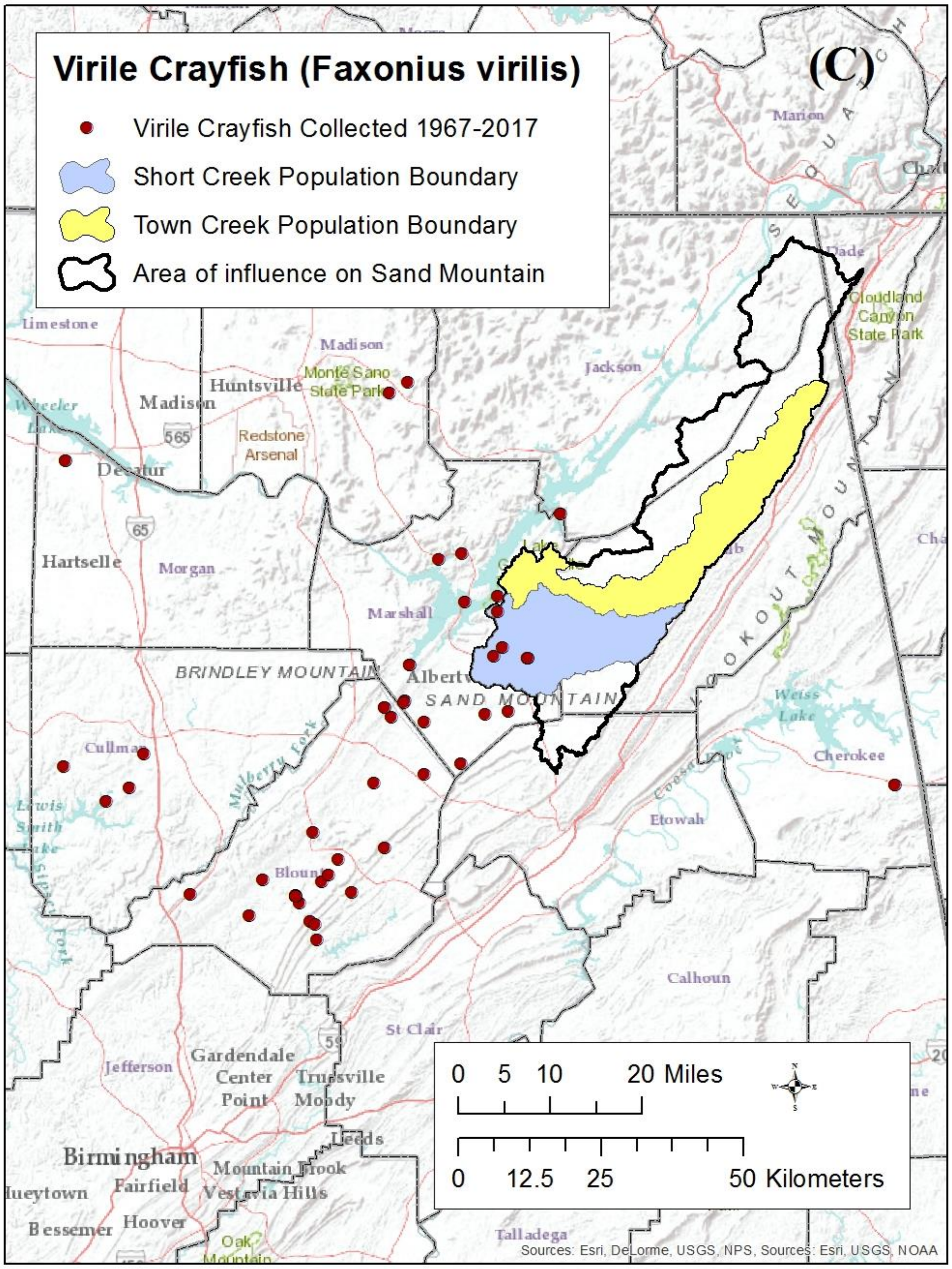

Figure 3-1C. Documented presence of virile crayfish within the historical range and surrounding area of slenderclaw crayfish during 1967 – 2017. Slenderclaw crayfish area of influence is outlined in black. Red circles are locations where virile crayfish were collected. Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data.

3.6 Conservation Efforts

3.6.1 State Protections

The slenderclaw crayfish is not currently listed as state threatened or endangered in Alabama. It is currently ranked as a priority 1 (highest conservation concern) species of greatest conservation need (ADCNR 2015, p. 237).

3.6.2 Water Quality Conservation

The Natural Resources Conservation Service (NRCS) National Water Quality Initiative (NWQI) program identified the Guntersville Lake – Upper Scarham Creek in DeKalb County as an Alabama Priority Watershed in 2015 (NRCS 2017). This watershed is within the historical range of the slenderclaw crayfish and is recognized to be in need of conservation practices as it was listed on the Alabama 303(d) list as impaired due to organic enrichment/low dissolved oxygen and ammonia as nitrogen (ADEM 2002, p. 4). The NWQI helps farmers, ranchers, and forest landowners improve water quality and aquatic habitats in impaired streams through conservation and management practices. Strategies include controlling and trapping nutrient and manure runoff and installation of cover crops, filter strips, and terraces.

TMDLs have been developed for siltation, ammonia, pathogens, organic enrichment/low dissolved oxygen, and pesticides in Scarham Creek (ADEM 2002, p. 5). Town Creek is currently on the 303(d) list for mercury contamination due to atmospheric deposition (ADEM 2016a p. Appendix C). A TMDL has been developed for Town Creek for organic enrichment/dissolved oxygen (ADEM 1996, entire). Through the 303(d) program, ADEM provides Section 319 funding targeting the watersheds to improve water quality. The Upper Scarham Creek Watershed was selected as a priority by ADEM for the development of a watershed management plan in 2014. In FY16, the DeKalb County Soil and Water Conservation District contracted with ADEM to implement the Upper Scarham Creek Watershed Project using Section 319 funding (ADEM 2016b, p. 39).

3.6.3 Other Conservation Actions

The U.S. Department of Agriculture (USDA) Farm Service Agency (FSA) spearheads the Conservation Reserve Program. This is a voluntary program that contracts with farmers and landowners to use their environmentally sensitive agricultural land for conservation benefit (USDA 2016, p. 1). The effort is active in the range of the slenderclaw crayfish and may improve water quality in the farming dominated landscape on Sand Mountain.

CHAPTER 4 - SPECIES NEEDS AND CURRENT CONDITION

In this chapter, we consider what the slenderclaw crayfish needs as a species for viability. First, we assess survey efforts to understand detection of the slenderclaw crayfish and occupancy of known sites. Then, we characterize the needs of the species and define methods for estimating current condition, including population resiliency, species representation, and species redundancy (the 3Rs), to support viability and reduce the likelihood of extinction. Finally, we evaluate the current condition of slenderclaw crayfish using demographic and habitat metrics used to characterize the 3Rs.

4.1 Survey Efforts and Discovery Analysis

Because the slenderclaw crayfish is relatively small and can be found in streams with large boulders, sampling can be difficult; therefore, we explored slenderclaw crayfish discovery in order to learn if survey efforts have documented the majority of potential known locations for this species. The objective of this analysis is to demonstrate the cumulative discovery of occupied sites in relation to the number of sites surveyed.

4.1.1 Survey Efforts Summary

Historically (1970 – 1974), the slenderclaw crayfish was found at five sites in the Town and Short Creek watersheds on Sand Mountain (Bouchard and Hobbs 1976, p. 7). More recent surveys (2005 and 2007) conducted at the historical sites did not find any slenderclaw crayfish (Kilburn et al. 2014, p. 117). In 2007, additional surveys were conducted at the type locality and a historical site on Scarham Creek that resulted in no collections of this species (C. Dillman pers. comm. 2017).

For this SSA, current survey efforts are defined as occurring from 2009 – 2017. In 2009, the slenderclaw crayfish was discovered at one new site in Shoal Creek, within the Short Creek watershed (Schuster 2017, unpublished data). In 2011, focused survey efforts for the slenderclaw crayfish were conducted at 55 sites within and outside of the species' historical range in Northeast Alabama and Northwest Georgia (Kilburn et al. 2014, p. 110). Each of the historical sites were sampled during the study. Methods used to conduct this study included seine net sets and visual searches. A seine was placed below cobble, boulders, or woody debris and others lifted and moved rocks while kicking and shuffling crayfish into the net. At small stream sites visual searches were used by turning over cobble, boulders, and woody debris and hand capturing crayfish or handpicking crayfish out in the open. All available microhabitats were sampled at sites and in-stream habitat characteristics, average substrate type, turbidity, water current type, percent cover, average depth, and average width were recorded for every collection site (Kilburn et al. 2014, p. 110). During this sampling attempt, the slenderclaw crayfish was found at only one site, which was the same Shoal Creek site as it was found in 2009 (Kilburn et al. 2014, p. 116).

From 2015 – 2017, a total of 71 unique sites in northeastern Alabama and northwestern Georgia were surveyed for the slenderclaw crayfish (Bearden et al. 2017, p. 17). This survey effort included the historical sites, the 2009 site on Shoal Creek, multiple visits to specific sites, and potential new sites. Crayfish sampling in larger streams was conducted with dip nets while visual searches were conducted at smaller stream sites. At each site, the net was set below boulders, cobble, or woody debris and held while lifting and moving rocks and kicking and shuffling crayfish into the net. Some small stream sites required only visual searches where cobble, boulders, and woody debris were turned over and crayfish were hand captured or handpicked in the open. General in-stream habitat characteristics, dominant substrate type, percent cover, water current type, turbidity, depth, and width were recorded for every collection site (Bearden et al. 2017, p. 12). From this survey effort, the slenderclaw crayfish was confirmed at the 2009 Shoal Creek site, rediscovered at the historical site on Shoal Creek, and was found at three new locations: one on Shoal Creek within the Short Creek population and two in the Town Creek population – including one on Bengis Creek and one on Town Creek (Bearden et al. 2017, p. 18).

4.1.2 Discovery Analysis Methods

For this analysis, the area used is based on the sampling extent from the 2011 survey effort within and outside of the species' historical range in Northeast Alabama and Northwest Georgia (Kilburn et al. 2014, entire). Data considered were from all stream surveys within this area since the species was discovered (Schuster 2017, unpublished data; C. Dillman pers. comm. 2017; Bearden et al. 2017, pp. 8-10, Kilburn et al. 2014, pp. 111-112). Records prior to the discovery of the slenderclaw crayfish and those records without collection dates were removed from the dataset. Collections with locations or waterbodies that were not in streams (caves, pitcher plant bogs, springs, or impoundments) were removed since the slenderclaw crayfish is not found in those environments. Locations that were surveyed multiple times were clustered using a buffer of 500 ft and were considered one unique site. The initial (unique) survey at a location that was surveyed multiple times was used for this analysis. The number of unique crayfish survey sites and number of positive unique slenderclaw crayfish sites was totaled per year separately, and the cumulative number of survey sites and positive slenderclaw crayfish sites was calculated. To visualize the survey effort for the slenderclaw crayfish, we displayed the number of positive collections (y-axis) against the number of crayfish surveys in streams within the range since the discovery of the slenderclaw crayfish (x-axis). We expected a positive linear relationship to occur if too few sites have been surveyed and the species is present at undiscovered, unique sites. If the chart approaches an asymptote, we inferred that all (or most) known locations of slenderclaw crayfish have been discovered.

4.1.3 Results and Discussion

Within the sampling extent from the 2011 survey effort (Kilburn et al. 2014, pp. 111-112), there were 208 unique crayfish (known stream sampling) survey sites sampled since the discovery of the slenderclaw crayfish in 1970 (Figure 4-1) (Schuster 2017, unpublished data; Bearden et al. 2017, and C. Dillman pers. comm. 2017). From 1970 – 2017, the slenderclaw crayfish was collected at 9 unique survey sites, and the line approaches an asymptote as indicated by logarithmic trendline (Figure 4-2). The jump in number of unique slenderclaw crayfish sites (intersect of 150, 7) can be attributed to the intense survey effort conducted specifically for the slenderclaw crayfish (Bearden et al. 2017, entire). Since the line approaches an asymptote, we have confidence that the majority of sites where the slenderclaw crayfish actually occurs have been discovered.

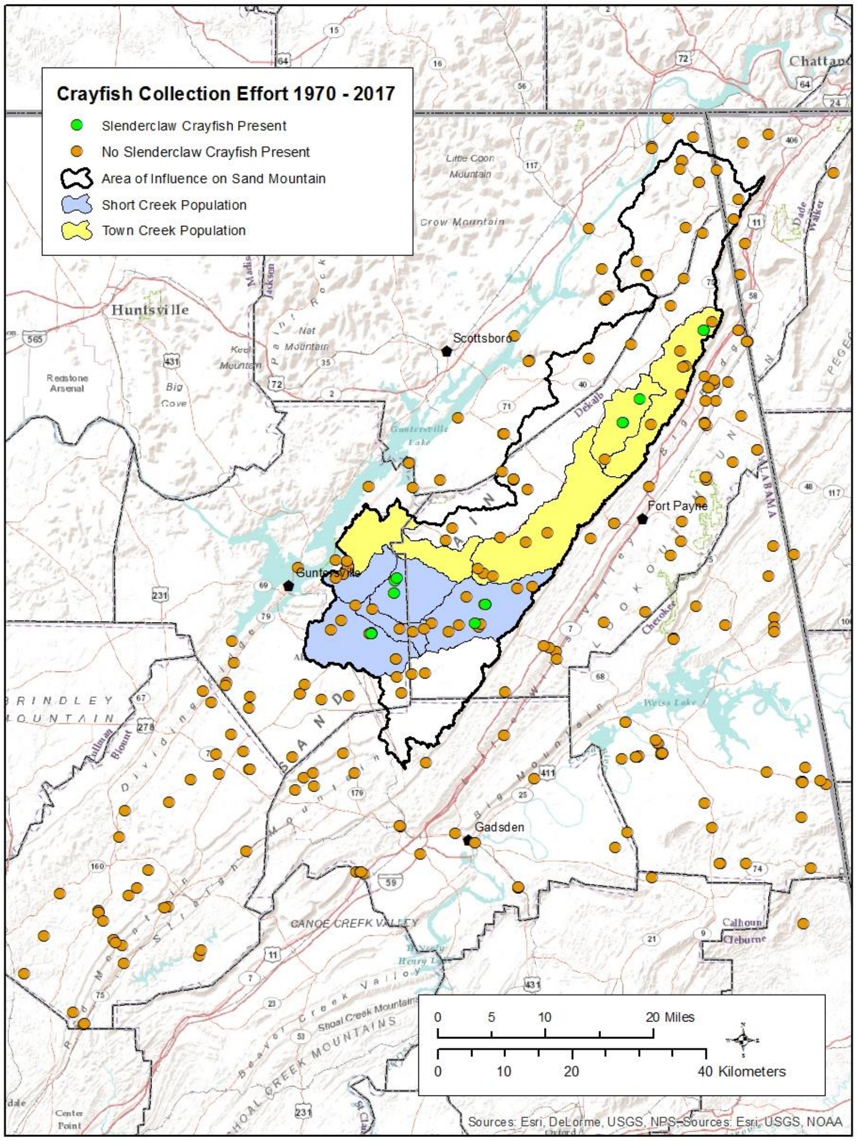

Figure 4-1. Unique crayfish survey sites sampled from 1970 – 2017 within the sampling extent from the 2011 survey effort (Kilburn et al. 2014). Slenderclaw crayfish area of influence on Sand Mountain is outlined in black. Green circles are unique crayfish survey sites with slenderclaw crayfish present. Orange circles are unique crayfish survey sites with slenderclaw crayfish absent. The Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data; C. Dillman pers. comm. 2017; Bearden et al. 2017; Kilburn et al. 2014.

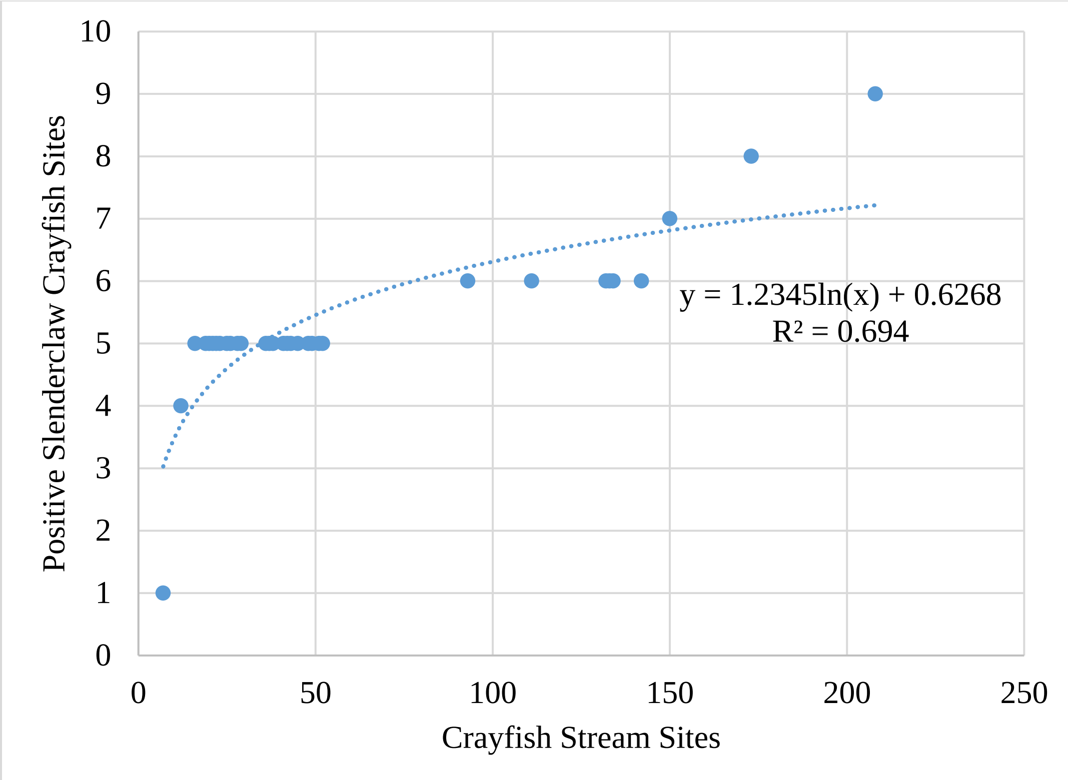

Figure 4-2. Discovery of slenderclaw crayfish (positive collections) sites in relation to unique crayfish sites surveyed from 1970 – 2017 within the sampling extent from the 2011 survey effort (Kilburn et al. 2014). Sources: Schuster 2017, unpublished data; C. Dillman pers. comm. 2017; Bearden et al. 2017; Kilburn et al. 2014.

4.2 Assessing Occupancy and Detection Probability

Cryptic species by definition are difficult to detect. Therefore, it is generally considered unwise to simply report observation data and count statistics when attempting to assess current populations of such species because changes in these data may be a product of random variation or changes in detectability rather than actual changes in population status (MacKenzie et al. 2002, p. 2248). To address these concerns, modeling techniques have been developed to provide better estimates of the proportion of sites occupied by a species. These modeling techniques estimate the probability of site occupancy (ψ) and detection probability (p) by separately considering the probability of detecting an individual and the probability that at least one individual is present (MacKenizie et al. 2002, pp. 2249-2250). Occupancy modeling is particularly helpful for environmental managers. For example, an estimate of site occupancy is useful in monitoring programs because it can help clarify a species' distribution, metapopulation dynamics, and habitat relationships. For this analysis, detection probability was also of particular interest because it clarifies uncertainty regarding field researchers' ability to successfully find slenderclaw crayfish across survey sites on Sand Mountain.

4.2.1 Model Development

Minimum requirements to assess occupancy and detection probability are repeated surveys and a record of detection or no-detection of the species of interest. Only one study (conducted by the Geological Survey of Alabama) on slenderclaw crayfish included repeated site visits as a part of its study design (Bearden et al. 2017, pp. 11-12). This study based its field methods on survey efforts conducted in 2011 (Kilburn et al. 2014, p. 110). The primary objective of both studies was to assess the distribution of slenderclaw crayfish. Therefore, both studies recorded detection history of crayfish species within streams on Sand Mountain. We combined detection history for the slenderclaw crayfish from both studies to create a more extensive dataset to analyze and estimate detection probability and occupancy.

Occupancy models can account for variation in detection and occupancy by using site and observation data as environmental covariates. Site data are environmental features recorded at the site. In this analysis, site data do not change over time. Observation data are recorded at each site during a particular observation. Observation data can vary with time. These covariates help to improve model fit as well as find species and habitat relationships if the study design allows. Site-level data was only available for the GSA study and included: site width, depth, stream substrate type, and an estimate of habitat condition. Site-level data was averaged across all observations by site. Observation level data collected by the GSA included: effort (in minutes), categorical stream velocity, number of surveyors present, air temperature, and number of crayfish (all species) collected. Number of surveyors and number of crayfish collected were the only observation data collected by both studies. Therefore, number of surveyors and number of crayfish collected were the only field collected observation data used for the occupancy analysis.

We included observation data (the number of surveyors, year surveyed, and ordinal day) as covariates with detection probability. We also tested whether site data influenced detection probability. Finally, we modeled the effects of site-level data on occupancy for the primary purpose of improving model fit. Candidate models were fit using the single season occupancy model (Mackenzie et al. 2002, entire) and compared with Akaike information criterion (AIC) (Burnham and Anderson 2004, entire) using the package unmarked (Fiske and Chandler 2011, entire) in program R (R Core Team 2017). We used a stepwise model building approach to construct 34 models with combinations of covariates that addressed a priori hypotheses about the system (Table 4-1). All models were then evaluated together and ranked based on AIC. Since the data spanned multiple years, the assumption of closed populations inherent with this class of occupancy model was likely violated due to long periods between surveys. Therefore, it is likely that all models produced in this analysis overestimates occupancy and underestimates detection probability (Rota et al. 2009, p. 1179; Wenger and Freeman 2008, p. 2955).

Table 4-1. Hypothesized relationships between recorded data and detection and/or occupancy.

Parameter	Detection Effect	Occupancy Effect
Ordinal Day	Detection varies by date surveyed (+ or -)	
Surveyors	Detection increases by the number of surveyors (+)	
Year	Detection varies by year (+or -)	
Average stream depth	Detection decreases with depth (-)	Occupancy varies by stream depth (+ or -)
Average stream width	Detection decreases with width (-)	Occupancy varies by stream width (+ or -)
Poultry farm density		Occupancy decreases with increasing farming density (-)
Large stream substrate	Detection decreases with presence of large substrate (-)	
Small stream substrate	Detection increases with presences of small substrate (+)	
Presence of other crayfish species		Occupancy decreases with increasing numbers of other

4.2.2 Results and Discussion

In the combined dataset, 19 sites were surveyed at least two times and were included in the final dataset for building occupancy models. The slenderclaw crayfish was detected at four of the 19 sites included in the dataset used in this analysis. Therefore, the proportion of sites at which the slenderclaw crayfish was detected (naïve occupancy) was 0.211. The naïve occupancy is the proportion of sites where the crayfish was found. Across the 19 sites retained in our dataset, 54 survey events occurred. Each site was visited an average of 2.84 times.

The top four models held 95% of the AIC weight and all include ordinal day as a covariate of detection probability, indicating that detection varied by the day of year when a survey for slenderclaw crayfish was conducted (Table 4-2). This result demonstrates the need for further research to clarify how seasonal variation influences the detection of the species. Three of the four top models included site data as covariates with detection probability. This result indicates that substrate type, site depth, and site size influence detection probability. Detection may be influenced by substrate type (e.g. fine sediment) because it can fill and remove interstitial spaces used by crayfish for shelter. An assessment of parameter estimates and 97% confidence intervals found weak or no relationship among the covariates used for detection or occupancy, with confidence intervals overlapping zero in all cases.

Table 4-2. Top models ranked by AIC and the model average estimate for occupancy (ψ) and detection probability (*p*).

Model	ΔAIC	AICwt	$\overline{\hat{\psi}}$	SE($\overline{\hat{\psi}}$)	$\hat{p}$	SE($\hat{p}$)
Ψ(Small Substrate^2)p(day^2)+(Large Substrate)	0.00	0.76	0.368	0.095	0.566	0.067
Ψ(Small Substrate^2)p(day^2)+(Stream Depth)	3.29	0.15	0.368	0.092	0.537	0.066
Ψ(Small Substrate^2)p(day^2)	7.63	0.017	0.433	0.091	0.365	0.053
Ψ(Small Substrate^2)p(day^2)+(Stream Width)	7.70	0.016	0.378	0.092	0.441	0.060
Model average	**-**	**-**	**0.369**	**0.094**	**0.555**	**0.066**

The model averaged estimate for occupancy (0.369) is greater than the naïve estimate of occupancy (0.211) (Table 4-2). Caution should be exercised when interpreting this result. Because the data used for building closed season occupancy models spanned multiple years and the assumption of closed populations inherent with this class of occupancy model was likely violated. Therefore, it is likely that all models produced in this analysis overestimate occupancy (Rota et al. 2009, p. 1179).

Based on the model averaged estimate for detection probability (0.555), the cumulative probability of detecting slenderclaw crayfish exceeded 90% after three survey events (Figure 4-3). This estimate is within the range of detection probabilities estimated for several crayfish species that found detection probability ranged 0.46 and 0.81 (Magoulick et al. 2017, p. 1). The occupancy estimates in that same study were found to be 0.20 (considered relatively rare) up to 0.60 (considered common).

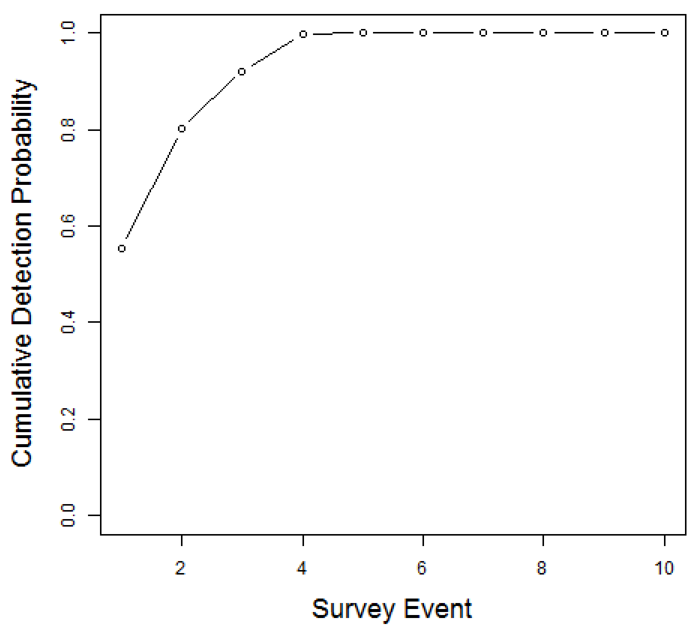

Figure 4-3. Cumulative probability of detection as a function of the number of surveys undertaken for slenderclaw crayfish.

This post hoc occupancy analysis used the best available data available to estimate detection probability (p) and occupancy (ψ) of slenderclaw crayfish in streams on Sand Mountain, Alabama. Generally, this type of analysis can be used to understand relationships between environmental variables and occupancy of a species at a given site or across a study area. The studies that provided the data for this analysis were not designed to answer these types of questions, which may explain the weak relationships between covariates with occupancy and detection. Ultimately, this was not the objective of this analysis. The primary goal of this analysis was to clarify the uncertainty regarding field researchers' ability to successfully detect this species, and the data available was more than adequate to answer this question. The results of the occupancy modeling increases our certainty that field researchers are able to detect the slenderclaw crayfish and that the currently documented range represents the actual range of the species (i.e. we would expect to discover few, if any, new sites to be occupied by slenderclaw crayfish).

4.2.3 Summary of Survey Effort Assessments

As summarized in Section 4.1, intensive survey effort has been conducted within and outside the historical range of the slenderclaw crayfish. There have been repeated surveys at unique sites, and the researchers have been able to find the slenderclaw crayfish when they survey for it. Based on the amount of survey effort for the slenderclaw crayfish, discovery analysis, and occupancy modeling, we are confident the researchers are able to find the slenderclaw crayfish, and the majority of sites where slenderclaw crayfish occurs have been discovered.

4.3 Species Needs and Methods for Estimating Current Condition

For the purpose of this assessment, we defined **viability** as the ability of the slenderclaw crayfish to sustain populations in the natural river systems over time (at least 20 years based on future scenarios – Chapter 5). Using the SSA framework, we described viability of the slenderclaw crayfish by estimating the current condition, and predicting the future condition (Chapter 5), of metrics used to assess **resiliency**, **representation**, and **redundancy** (the 3Rs).

4.3.1 Population Resiliency

Each population (Short Creek and Town Creek) of the slenderclaw crayfish needs to be able to withstand, or be *resilient* to, stochastic events or disturbances (e.g. drought, major storms and flooding, accidental discharge of pollutants into streams, or fluctuations in reproduction rates). To be resilient, these populations need to have an adequate number of individuals, cover a large enough area (multiple sites within a population) that a localized event does not eliminate a population, and have connectivity among sites within a population such that areas could be repopulated if local site extirpations were to occur. To assess current population resiliency of slenderclaw crayfish, we used abundance, evidence of reproduction, presence of virile crayfish, and water quality condition by population.

Despite the number of current survey efforts, slenderclaw crayfish were found in low abundance at a few sites within both populations. Assessing the demographic factors of abundance and evidence of reproduction lead to an understanding of what low abundance at a few sites means for the current population resiliency of the slenderclaw crayfish. Abundance was the total number of slenderclaw crayfish collected at sites within each population from 2009 – 2017, and evidence of reproduction was the total number of juveniles collected at sites within each population, years 2015 – 2017. Abundance conditions were estimated based on the collections of the co-occurring crayfish, ambiguous crayfish (*C. striatus*), within the range and surrounding area of the slenderclaw crayfish. We referenced this species because it is in the same genus as the slenderclaw crayfish and is not of conservation concern. The ambiguous crayfish was collected at substantially larger numbers (more than 350 individuals) compared to the slenderclaw crayfish during the 2009 – 2017 collection period (G. Schuster 2017, unpublished data; C. Taylor 2017, unpublished data). Evidence of reproduction conditions were based on the original captures by Bouchard and Hobbs in 1970 – 1974 that found a total of 56 juveniles over four years and documented females with glair glands. We used data from the most recent three years since this is the likely lifespan of the slenderclaw crayfish (Bouchard and Hobbs 1976; G. Schuster pers. comm 2017; G. Schuster 2017, unpublished data; C. Taylor 2017, unpublished data).

Two habitat factors, presence of virile crayfish and water quality condition, were assessed to understand current population resiliency of slenderclaw crayfish. Virile crayfish has been known to have an ecological advantage over native crayfishes (Clark and Lester 2005, p. 168). This non-native species has been documented at the slenderclaw crayfish type locality in Short Creek and other sites within the range of slenderclaw crayfish. Since the virile crayfish is a larger crayfish that tends to migrate and is a strong competitor and the slenderclaw crayfish has low abundance and is a smaller bodied crayfish, we inferred that once virile crayfish is established at a site it will out-compete the slenderclaw crayfish. Presence of virile crayfish was based on current presence or absence at a site, within the boundary of a population, in an adjacent watershed at the HUC12 level, or within 100 or 200 miles. The virile crayfish is a fierce competitor and is able to spread rapidly (B. Williams pers. comm. 2018), therefore the closer the virile crayfish's range is to the slenderclaw crayfish's range, the lower the resiliency. Virile crayfish have been documented to move at a rate of approximately 1640 ft/month (500 m/month) from known locations (Wong 2014, p. 4). As a note, the data assessed for presence of virile crayfish only included DeKalb, Marshall, and immediate surrounding counties in Alabama (Shuster 2017, unpublished data; Taylor 2017, unpublished data); we did not assess the spread of the virile crayfish outside of these counties.

As stated in Section 3.5, crayfish generally have a higher tolerance to poor water quality than other aquatic species; however, aquatic macroinvertebrates are likely the exclusive food source for juvenile slenderclaw crayfish and can be impacted by poor water quality conditions. Water quality condition was a function of current known water quality issues occurring in creeks or streams within each population. The water quality criteria are based on levels developed by the EPA and ADEM to protect fish and wildlife (ADEM 2017, entire), and exceedance of these values is likely to harm animal or plant life (EPA 2018b).

To summarize the overall current population resiliency of the slenderclaw crayfish, we ranked the slenderclaw crayfish populations into a current condition category (High, Moderate, Low, and Very Low) based on the demographic and habitat factors outlined above (Table 4-3). The current condition category is a qualitative estimate based on the analysis of abundance, evidence of reproduction, presence of virile crayfish, and water quality condition. Overall population current condition rankings were determined by combining the demographic and habitat factor rankings, which were weighted equally.

Table 4-3. Demographic and habitat factors assessed and used to create current condition categories to determine the current population resiliency of the slenderclaw crayfish. Information from within the entire population boundary was used to determine condition category.

Condition Category	Abundance*	Evidence of Reproduction†	Presence of Virile Crayfish	Water Quality Condition
High	100 or more individuals captured	At least 30 juveniles found within last 3 years	No virile crayfish found within 200 miles	No known water quality issues
Moderate	6-99 individuals captured	20-30 juveniles found within last 3 years	No virile crayfish found within 100 miles	Improved conditions after known degraded water quality Improved quality condition for food sources of the slenderclaw crayfish
Low	1-5 individuals captured	1-19 juveniles found within last 3 years	Virile crayfish present within population boundary or in adjacent watershed (HUC12)	Known impacts to the slenderclaw crayfish food sources Current issues identified by ADEM 303(d) Impaired Waters or other studies at one or more sites within a population
Very Low	1 or fewer individuals captured	0 juveniles found within the last 3 years	Virile crayfish present at 1 or more site(s) within a population where the slenderclaw crayfish are now absent	Unable to support the slenderclaw crayfish survival

*Abundance conditions were approximated based on the collections of the co-occurring crayfish, ambiguous crayfish (*Cambarus striatus*), within the range and surrounding area of the slenderclaw crayfish. We referenced this species because it is in the same genus as the slenderclaw crayfish and is not of conservation concern. The ambiguous crayfish was collected at substantially larger numbers compared to the slenderclaw crayfish during the 2009 – 2017 collection period. Sources: G. Schuster 2017, unpublished data; C. Taylor 2017, unpublished data.
†Evidence of reproduction conditions were based on the original captures by Bouchard and Hobbs in 1970 – 1974 that found a total of 56 juveniles over four years. We used a time span of three years since this is the likely lifespan of the slenderclaw crayfish. Sources: Bouchard and Hobbs 1976; G. Schuster pers. comm. 2017; G. Schuster 2017, unpublished data; C. Taylor 2017, unpublished data.

4.3.2 Species Representation and Redundancy

Representation reflects a species' adaptive capacity to changing environmental conditions over time and can be characterized by genetic and ecological diversity within and among populations. For slenderclaw crayfish, we used two metrics to assess representation: 1) habitat variability and 2) morphological variability. For the slenderclaw crayfish to exhibit adequate representation, resilient populations should occur in the two slightly different habitat types as described in Section 2.4 across the historical range. This includes streams with predominantly large boulders and fractured bedrock, broader stream widths, no turbidity, and greater depths. The second type of stream habitat includes larger amounts of smaller substrate types with a mix of sand, gravel, and cobble, narrower stream widths, no turbidity, and shallower depths (R. Bearden pers. comm. 2017). In addition, resilient populations should maintain individuals with minor morphological differences (see Section 2.2). Although we are uncertain of how the variations of morphology in slenderclaw crayfish reflect the species' adaptive capacity, these variations should be preserved to maintain representation into the future. To maintain existing adaptive capacity, it is important to have resilient populations with sites in each population in the two habitat types and individuals in each population with morphological variations.

The metric of redundancy reflects a species' ability to persist after experiencing extreme catastrophic events. Redundancy is measured by assessing the number and distribution of resilient populations throughout a species' range. Species that are well-distributed across their historical range are considered less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll et al. 2010, entire; Redford et al. 2011, entire). Redundancy for the slenderclaw crayfish is characterized by having multiple resilient populations and occupied sites distributed throughout its range. These populations should also maintain natural levels of connectivity between them; currently, the Town Creek population is separated from the Short Creek population due to Guntersville Lake resulting in reduced connectivity. For redundancy, we evaluated the current distribution of slenderclaw crayfish populations through their present-day spatial locations.

4.4 Current Condition

The slenderclaw crayfish is currently found in tributaries on the south side of Guntersville Lake on the Tennessee River in Marshall and DeKalb counties, Alabama, and includes two populations: Short Creek and Town Creek (Figure 2-5). The slenderclaw crayfish is currently extant at three sites within the Short Creek population and two sites within the Town Creek population. The species has been extirpated from four historically occupied sites including the type locality within the Short Creek population.

4.4.1 Current Population Resiliency

To assess the current condition of slenderclaw crayfish, we assessed abundance (total number collected in each population years 2009 – 2017), evidence of reproduction (number of juveniles collected in each population years 2015 – 2017), presence of virile crayfish, and water quality condition by population. Then, we ranked the slenderclaw crayfish populations into a current condition category (High, Moderate, Low, and Very Low) based on the demographic and habitat factors assessed in the following Sections.

4.4.1.1 Assessing Abundance and Evidence of Reproduction in the Short Creek Population

The slenderclaw crayfish was historically (1970 – 1974) documented at four sites within the Short Creek population: one location in Short Creek, two locations in Scarham Creek, and one location in Shoal Creek (Bouchard and Hobbs 1976, p. 7). Of these four historical sites, the slenderclaw crayfish is no longer found at three sites (Short Creek and Scarham Creek locations) despite repeated survey efforts. The presumed extirpated site on Short Creek is now occupied by the non-native virile crayfish (Schuster 2017, unpublished data; Taylor 2017, unpublished data). Through a recent (2015 – 2017) intensive sampling effort, two additional sites have been documented on Shoal Creek within the Short Creek population (Figure 2-5) (Bearden et al. 2017, pp. 17-18). Across current survey efforts (2009 – 2017), there were six positive collections with a total of 28 slenderclaw crayfish collected within the Short Creek population (Table 4-4). Of these, only 2 juveniles were collected during current survey years.

Table 4-4. Abundance (total number collected) and evidence of reproduction for slenderclaw crayfish (*Cambarus cracens*) within the Short Creek population. Values represent the current condition based on data collected from 2009 – 2017. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data; Bearden et al. 2017; Kilburn et al. 2014.

Year	Number of Positive Collections	Evidence of Reproduction	Total Number Collected
2009	1	No	6
2011	1	Yes, 1 juvenile	12
2015	2	No	7
2016	0	No	0
2017	2	Yes, 1 juvenile	3
Total Collected from Short Creek			28

4.4.1.2 Assessing Abundance and Evidence of Reproduction in the Town Creek Population

Historically (1970 – 1974), the slenderclaw crayfish was found at one location on Bengis Creek in the Town Creek population (Bouchard and Hobbs 1976, p. 7). Repeated attempts have failed to capture the species at this historical site in recent years (since 2009), therefore it is considered extirpated. During current survey (2009 – 2017) efforts, the slenderclaw crayfish has been documented at two additional sites, including a new site in Bengis Creek and a new site in Town Creek, both of which are within the Town Creek population (Figure 2-5); however, the species was only found at these sites (and the entire Town Creek population) during 2016 sampling efforts (Bearden et al. 2017, p. 18). During current survey efforts, there were two positive collections with a total of 4 slenderclaw crayfish collected within the Town Creek population (Table 4-5). Of these 4 individuals, only 2 juveniles were collected during current survey years.

Table 4-5. Abundance (total number collected) and evidence of reproduction for slenderclaw crayfish (*Cambarus cracens*) within the Town Creek population. Values represent the current condition based on data collected from 2009 – 2017. Sources: Schuster 2017, unpublished data; Taylor 2017, unpublished data; Bearden et al. 2017; Kilburn et al. 2014.

Year	**Number of Positive Collections**	**Evidence of Reproduction**	**Total Number Collected**
2009	0	No	0
2011	0	No	0
2015	0	No	0
2016	2	Yes, 2 juveniles	4
2017	0	No	0
Total Collected from Town Creek			4

4.4.1.3 Assessing Presence of Virile Crayfish Metric

Within the historical range of the slenderclaw crayfish, the non-native virile crayfish has been documented at an increasing number of sites in recent years (Figure 3-1). In 2015, virile crayfish (*Faxonius virilis*) was first documented with one individual found at the type locality for the slenderclaw crayfish in Short Creek (Schuster 2017, unpublished data; Taylor 2017, unpublished data). In 2016, virile crayfish was found at two sites in Drum Creek within the Short Creek population boundary and at the confluence of Short Creek and Guntersville Lake (Schuster 2017, unpublished data; Taylor 2017, unpublished data). Twenty virile crayfish were found again at the type locality in Short Creek during 2017 (Taylor 2017, unpublished data). Also during 2017, the non-native crayfish was documented at four new sites in adjacent HUC12s outside of the Short Creek population boundary. Juvenile virile crayfish have been collected in the Short Creek population indicating that the species is established (Taylor 2017, unpublished data). To date, no virile crayfish have been documented within the Town Creek population boundary (Schuster 2017, unpublished data; Taylor 2017, unpublished data).

4.4.1.4 Assessing Water Quality Condition Metric

To understand water quality condition as a metric for resiliency, we first considered the land-use within and around each population of slenderclaw crayfish. Within the Short Creek population, the predominant land cover type is hay/pasture (1,419 acres (5.7 km^2)), followed by deciduous forest (420 acres (1.7 km^2)), mixed forest (351 acres (1.4 km^2)), and cultivated crops (264 acres (1.1 km^2)) (Homer et al. 2015, National Land Cover Dataset (NLCD) 2011, Figure 4-4). For the

Town Creek population, the predominant land cover type also is hay/pasture (1570 acres (6.4 km^2)), followed by deciduous forest (907 acres (3.7 km^2)), mixed forest (417 acres (1.7 km^2)), and cultivated crops (333 acres (1.3 km^2)) (Homer et al. 2015, NLCD 2011, Figure 4-5). As outlined in Section 3.2, poultry farming is an important industry on Sand Mountain. There are 0.476 poultry farms per 100 acres (1.179 poultry farms per km^2) within the Short Creek population and 0.347 poultry farms per 100 acres (0.857 poultry farms per km^2) in the Town Creek population (Bearden et al. 2017, pp. 30-31).

Within the Short Creek population, Scarham Creek was placed on the 303(d) list in 1996 for impacts from pesticides, siltation, ammonia, low dissolved oxygen/organic enrichment, and pathogens from agricultural sources; this section stretched 24 miles from its confluence of Short Creek to its source (ADEM 2013, p. 1). In 2004, Scarham Creek was removed from the 303(d) list. TMDLs have been developed for low dissolved oxygen and organic loading, pesticides, ammonia, pathogen impairments, and for siltation in Scarham Creek (ADEM 2002, p. 5). Within the Town Creek population, all of Town Creek is currently on the 303(d) list for mercury contamination due to atmospheric deposition (ADEM 2016a, p. Appendix C). A TMDL has been developed for Town Creek for organic enrichment and dissolved oxygen (ADEM 1996, p. 1). One identified source of wastewater discharge is from Hudson Foods on Town Creek near Geraldine, Alabama (ADEM 1996, p. 1).

During recent survey efforts for the slenderclaw crayfish, water quality analysis indicated that water quality was impaired due to nutrients and bacteria within the Short Creek population and levels of atrazine may be of concern in the watershed (Bearden et al. 2017, p. 32). In Bengis Creek (Town Creek population), water quality analysis found lead measurements that exceeded the acute and chronic aquatic life criteria set by the Environmental Protection Agency (EPA) and ADEM (Bearden et al. 2017, p. 32; ADEM 2017, p. 10-7). These criteria are based on levels developed by the EPA and ADEM to protect fish and wildlife (ADEM 2017, entire), and exceedance of these values is likely to harm animal or plant life (EPA 2018b). The study also documented elevated ammonia in Town Creek within the Town Creek population (Bearden et al. 2017, p. 27). In late summer and fall, potential eutrophication likely stemming from low water conditions, elevated nutrients, and low dissolved oxygen was documented within both populations (Bearden et al. 2017, p. 31).

Understanding the water quality condition within each population is important since the slenderclaw crayfish, specifically juveniles, likely feed on aquatic macroinvertebrates. Poor water quality from increased nutrients, ammonia, and other contaminants impacts aquatic macroinvertebrates, and therefore, is a factor in the viability of the slenderclaw crayfish. In 2009, a macroinvertebrate and habitat assessment was conducted in Scarham Creek and discovered the macroinvertebrate community to be in poor condition, although the habitat was found to be optimal (ADEM 2009, p. 1); in 2013, the macroinvertebrate community was found to be in fair condition with an optimal habitat condition (ADEM 2013, p. 1).

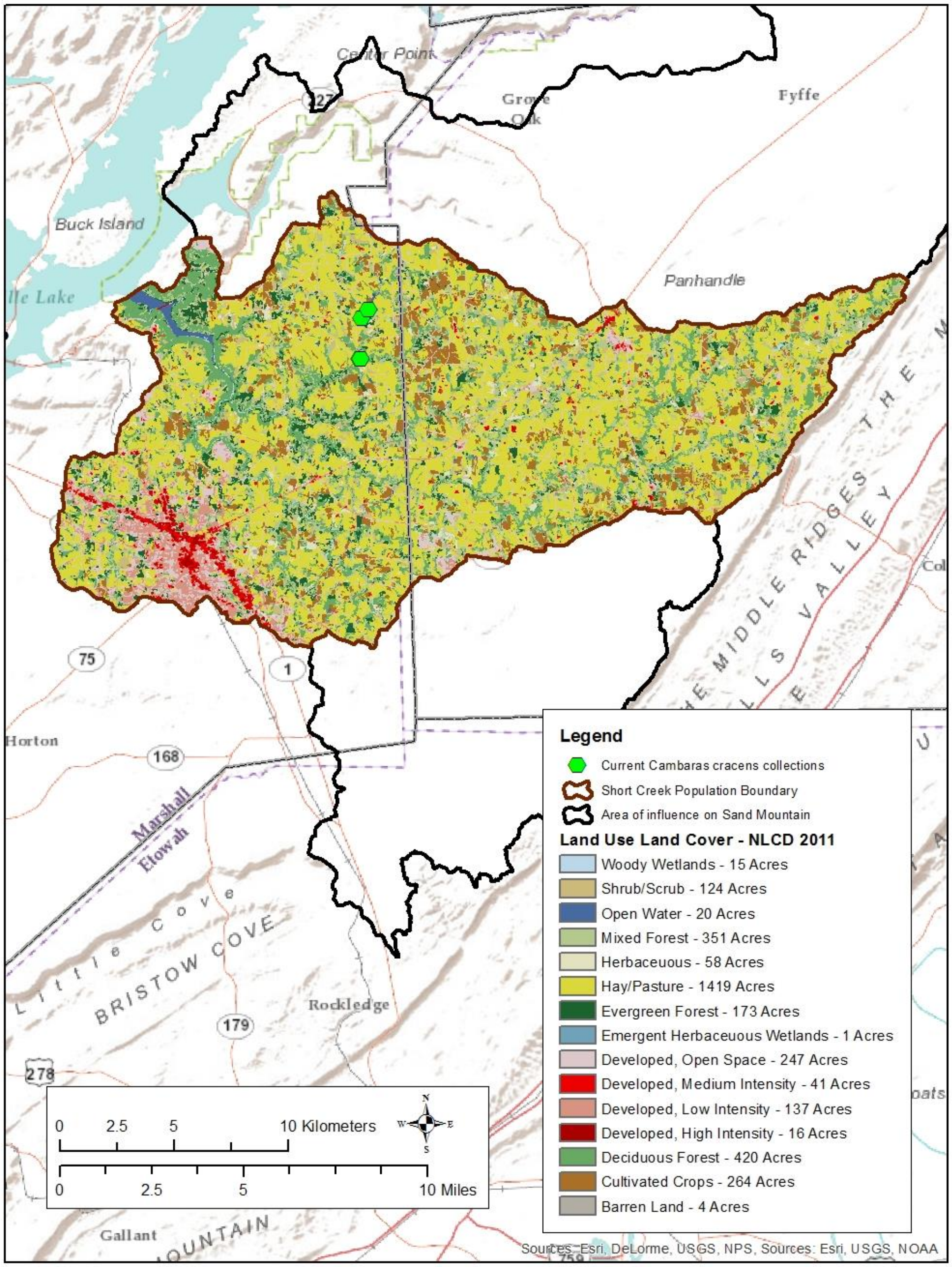

Figure 4-4. Land Use Land Cover occurring within the Short Creek population of the slenderclaw crayfish. Slenderclaw crayfish area of influence is outlined in black. Short Creek population boundary is outlined in red. Source: NLCD 2011 – Homer et al. 2015.

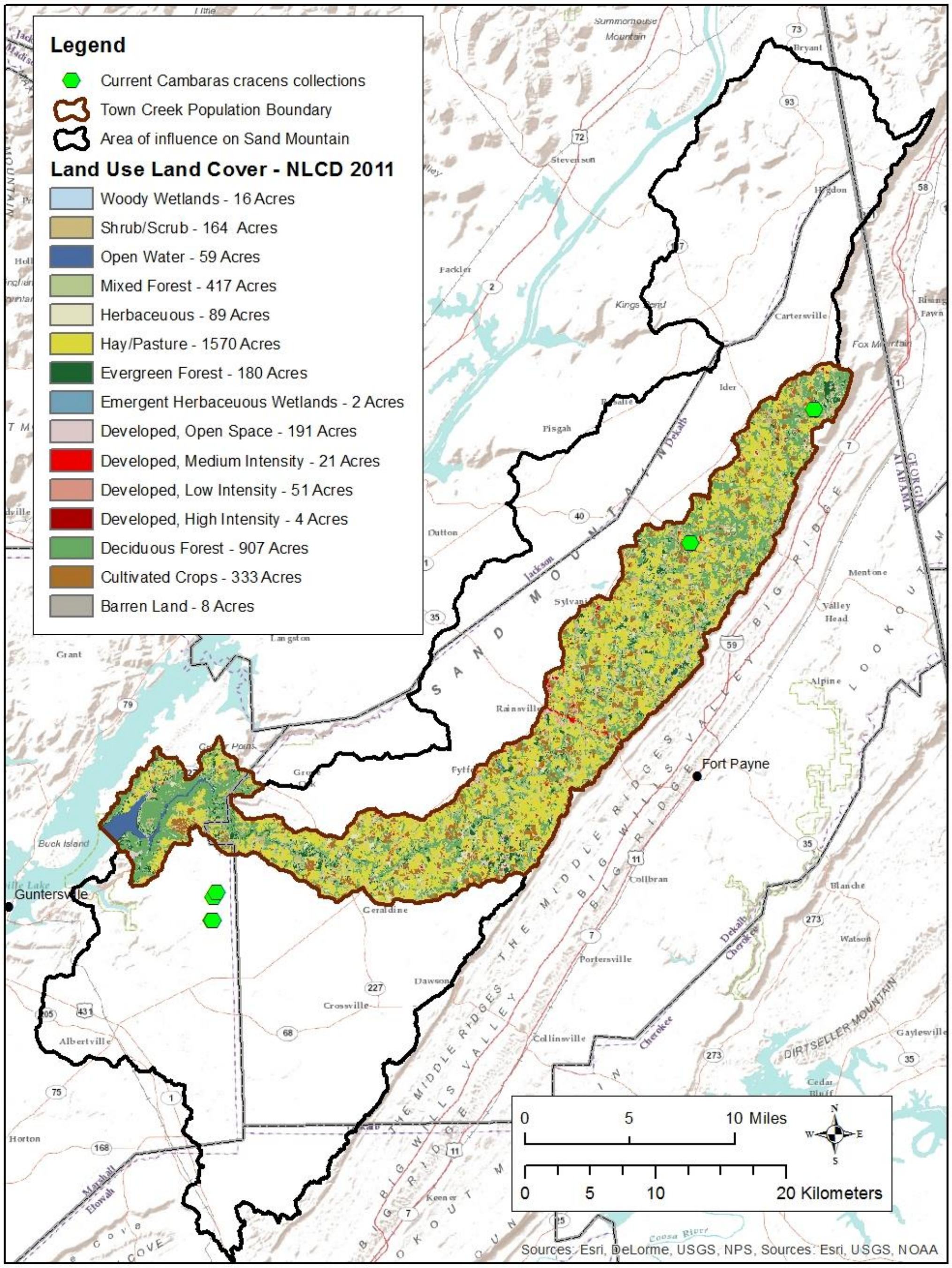

Figure 4-5. Land Use Land Cover occurring within the Town Creek population of the slenderclaw crayfish. Slenderclaw crayfish area of influence is outlined in black. Town Creek population boundary is outlined in red. Source: NLCD 2011 – Homer et al. 2015.

4.4.1.5 Current Population Resiliency of the Slenderclaw Crayfish

In terms of resiliency, both populations of the slenderclaw crayfish are presently in low condition overall (Table 4-6). While the Short Creek population exhibits a moderate number of individuals captured (28 total individuals during 2009 – 2017), there is very limited evidence of reproduction (only 1 juvenile collected within the last 3 years), virile crayfish occupies a site previously occupied by slenderclaw crayfish and it is found at other sites within the population, and water quality is compromised (as evidenced by elevated levels of nutrients, bacteria, ammonia, siltation, detection of atrazine, potential eutrophication, and low dissolved oxygen levels) (Bearden et al. 2017, pp. 31-32). Though siltation has been documented as an issue in Scarham Creek (Short Creek population), this issue is not seen as an impact across the entire range of the slenderclaw crayfish. The Town Creek population is also in low current condition, as all of the factors evaluated were ranked low. Generally speaking, populations need enough individuals, within habitat patches of adequate area and quality, to maintain survival and reproduction in spite of disturbance. Overall, given the current condition of both populations of slenderclaw crayfish, these populations are likely to have limited ability to respond to stochastic events (e.g., disturbance).

Table 4-6. Current resiliency of the slenderclaw crayfish populations determined by assessing demographic and habitat factors used to create current condition categories. See Table 4-3 for current condition categories.

Population	Abundance	Evidence of Reproduction	Presence of Virile Crayfish*	Water Quality Condition	Overall Resiliency
Short Creek	Moderate	Low	Very Low	Low	Low
Town Creek	Low	Low	Low	Low	Low

*Lower condition does not reflect a lower presence of virile crayfish; this indicates resiliency of the slenderclaw crayfish populations in response to proximity of the virile crayfish.

4.4.2 Current Species Representation

The slenderclaw crayfish is a narrow endemic which has only two known populations occupying slightly different watersheds, Short Creek and Town Creek. In terms of representative characteristics, the habitat variability features occurring in the Short Creek and Town Creek populations are differentiated by stream width, stream depth, and substrate size. The Short Creek population of slenderclaw crayfish occurred in streams with predominantly large boulders and fractured bedrock, broader stream widths, no turbidity, and greater depths; and the Town Creek population occurred in streams with larger amounts of smaller substrate types with a mix of sand, gravel, and cobble, narrower stream widths, no turbidity, and shallower depths (R. Bearden pers. comm. 2017). The slenderclaw crayfish once exhibited some morphological difference across sites, which included spination of the carapace being more pronounced at the type locality in the Short Creek population; however, slenderclaw crayfish are considered extirpated from the type locality after multiple failed collection attempts. This may be due to the presence of virile crayfish at the site. At this time, there is no known genetic variation as this analysis has not been conducted. At present, the slenderclaw crayfish has two populations in low condition (resiliency) with habitat types that vary between populations. Therefore, the species has some level of adaptive capacity, but given the low resiliency of both populations of the slenderclaw crayfish, current representation is reduced.

4.4.3 Current Species Redundancy

The slenderclaw crayfish exhibits low natural redundancy given its narrow range. Currently, there are two populations spread throughout the species' historical range with three extirpated historical sites in the Short Creek population and one extirpated historical site in the Town Creek population, and thus the slenderclaw crayfish has limited redundancy. In addition, connectivity between the Short Creek and Town Creek populations is likely low due to Guntersville Lake. Multiple sites in the same population may allow recolonization following a catastrophic event (e.g., a spill) which affects a large proportion of a population; however, given the species' limited redundancy and current low resiliency in both populations, it might be difficult to re-establish an entire population affected by a catastrophic event without human intervention, as the connectivity between the two populations is low. In addition, the currently occupied sites in the Short Creek population are in a single tributary, and one catastrophic event could impact the entire population.

CHAPTER 5 – FUTURE CONDITIONS AND VIABILITY

We have considered what the slenderclaw crayfish needs for viability and the current condition of those needs (Chapters 2 and 4), and we reviewed the factors that are driving the historical, current, and future conditions of the species (Chapter 3). We now consider what the species' future conditions are likely to be. We apply our future forecasts to the concepts of resiliency, redundancy, and representation to describe the future viability of the slenderclaw crayfish.

5.1 Introduction to Projections and Scenarios

To assess the future condition of the slenderclaw crayfish, we have forecasted what the slenderclaw crayfish may have in terms of the 3Rs under three plausible future scenarios. As outlined in Chapter 3, hydrologic alteration, land-use change, and non-native virile crayfish were the factors identified as affecting the slenderclaw crayfish in the future. Therefore, we projected how these factors would change over time in order to develop our future scenarios to assess abundance, presence of virile crayfish, and water quality condition by population at three time periods: 2020, 2030, and 2040. The time steps begin in 2017, as this was the end of our current condition timeframe. The current low abundance is also a factor that will affect slenderclaw crayfish in the future, and this factor was assessed for each scenario considering the rate of spread of the virile crayfish. In addition, we anticipated no voucher (removal of adults or juveniles for identification) collections of the slenderclaw crayfish will occur in the future.

To summarize the overall population resiliency of the slenderclaw crayfish in the future, we ranked the slenderclaw crayfish populations into a condition category (High, Moderate, Low, Very Low, and Extirpated) based on the demographic and habitat factors outlined in Section 4.3 (Table 4-3). For future condition, the condition category is a qualitative estimate based on the analysis of abundance, presence of virile crayfish, and water quality condition factors. Overall population future condition rankings were determined by combining the demographic and habitat factor rankings. An extirpated condition was scored for condition factors when no slenderclaw crayfish would be collected (abundance), virile crayfish were found at more than one site and the slenderclaw crayfish is now absent in a population (presence of virile crayfish), or water quality could no longer support the slenderclaw crayfish (water quality condition).

For these future condition rankings, populations in high condition were defined as those with high resiliency at the end of the predicted time periods (2020, 2030, and 2040). Populations in high condition are expected to persist into the future beyond these time periods and have the ability to withstand stochastic events. Populations in moderate condition were defined as having lower resiliency than those in high condition but are still expected to persist beyond the time periods. Populations in low and very low conditions were defined as having low and very low resiliency, respectively, and may not be able to withstand stochastic events; therefore populations were much less likely to persist beyond the time periods and may become extirpated in the future.

5.2 Projections

5.2.1 Precipitation Change

In the future, a further reduction in water availability in Sand Mountain streams may negatively influence the viability of the slenderclaw crayfish since the crayfish is adapted to living in streams and has not been found in dry channels. Therefore, to understand how precipitation will change in the future, we used the USGS's National Climate Change Viewer (NCCV) (Alder and Hostetler 2013, entire) to predict change in precipitation through 2040. The representative concentration pathway (RCP) 4.5 emissions scenario was applied to our three time steps within the Guntersville Lake, Alabama, Georgia, Tennessee HUC8 and future and historical climate predictions from 30 of the downscaled models for this RCP emission scenario were included. These scenarios are plausible pathways toward reaching a target radiative forcing (the change in energy in the atmosphere due to greenhouse gases) by the year 2100 (Moss et al. 2010, p. 752). RCP emissions scenarios help scientists capture the most plausible range of outcomes for climate futures based on uncertainties inherent in the natural and socio-economic environment.

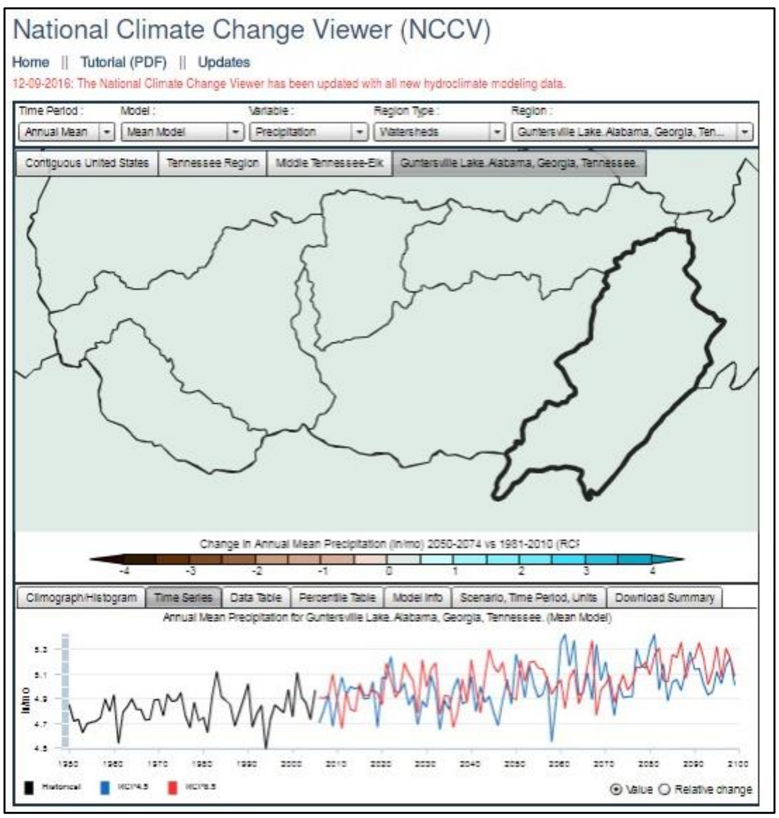

Figure 5-1. Change in annual mean precipitation for the Guntersville Lake, Alabama, Georgia, Tennessee HUC8 to 2100, RCP 8.5. Source: Alder and Hostetler 2013, NCCV USGS.

Results from the precipitation modeling in this region indicate a general positive trend in precipitation to the year 2040 and beyond to 2100 (Figure 5-1). The map displays the results of the RCP 8.5 model. The RCP 4.5 mean model forecasted approximately 4.9 inches of precipitation per month in 2020, 4.8 inches/month in 2030, and 5.1 inches/month in 2040.

5.2.2 Land-Use Change

While land-use change, and specifically urbanization, has a variety of effects on ecosystems, it will likely also influence the ability of species to respond to climate change, by creating movement barriers for species that cannot survive in cities and corridors for species that can (Terando et al. 2014, p. 1). The expansion of development indicates increasing connectedness in the Southeast and favorable conditions for urban-adapted species, while other species will experience reduced habitat area and increased difficulty in migration and dispersal (Terando et al. 2014, p. 7). The largest conversion in land cover type in the Southeast for the next 50 years is from agricultural to urban land use (Terando et al. 2014, pp. 4-5). In the case of slenderclaw and other native crayfish species, it was inferred that expansion of urban areas will reduce available habitat in areas where they occur, as well as increasing impervious surface and resultant runoff of oils and other substances which reduce the quality of water the populations require. To explore potential land-use change and urbanization on Sand Mountain and the surrounding area, we used the SLEUTH-3r (Slope, Land use, Excluded, Urban, Transportation and Hillshade) urban-growth model, as modified, to project urban growth at 2020, 2030, and 2040 (Belyea and Terando 2013, entire; Terando et al. 2014, entire). This model uses land cover change modeling, cellular automata (a model approach where landscape is divided into a grid of cells), and terrain mapping to predict urban growth (Jantz et al. 2009, entire; Belyea and Terando 2013, entire). Input datasets for the model were produced in ESRI ArcGIS. A process for classifying past urbanized areas was informed by both the 2001 NLCD and the 2006 U.S. Census Bureau (USCB) TIGER Line Data of local street network information (Terando et al. 2014, p. 2).

Results from the SLEUTH model indicate little change in land use by 2020 (Figure 5-2). By 2030, the model predicted slightly more growth in rural areas (Figure 5-3), and by 2040, the model predicted higher growth in the Rainsville, Alabama area within the Town Creek population (Figure 5-4).

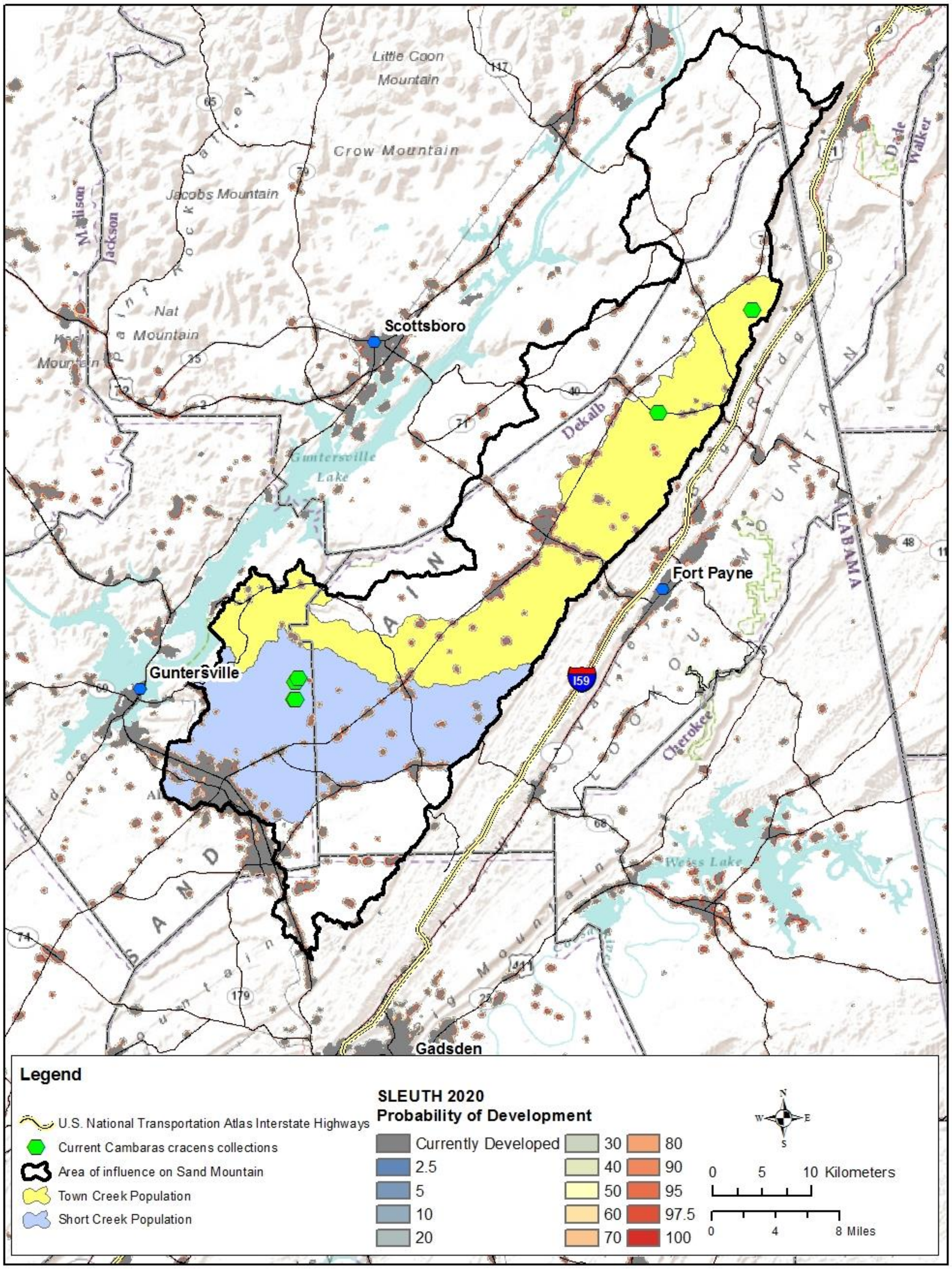

Figure 5-2. Projected urban land cover on and around Sand Mountain based on the SLEUTH model projected to 2020. Area of influence on Sand Mountain for the slenderclaw crayfish is outlined in black. The Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow.

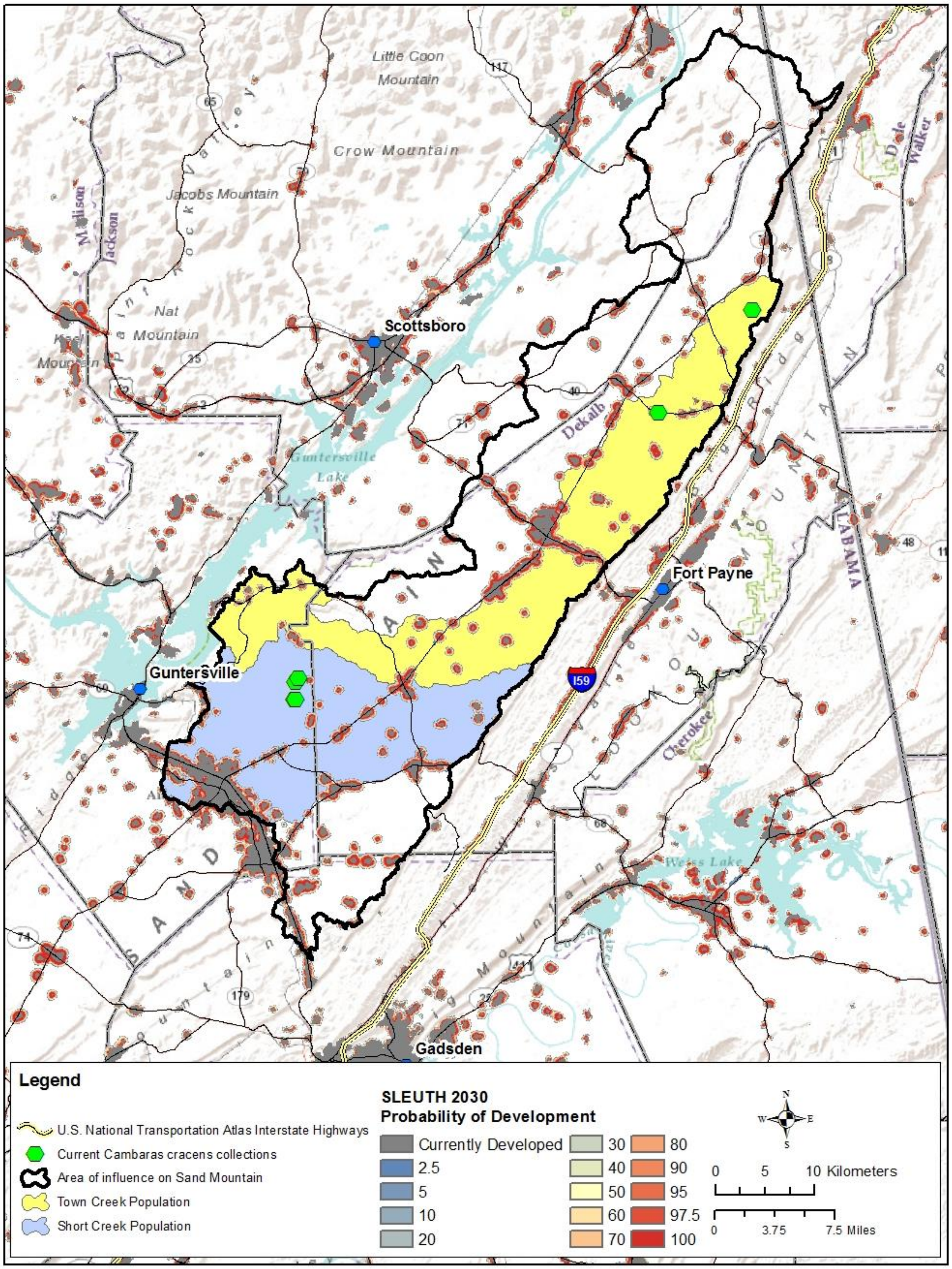

Figure 5-3. Projected urban land cover on and around Sand Mountain based on the SLEUTH model projected to 2030. Area of influence on Sand Mountain for the slenderclaw crayfish is outlined in black. The Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow.

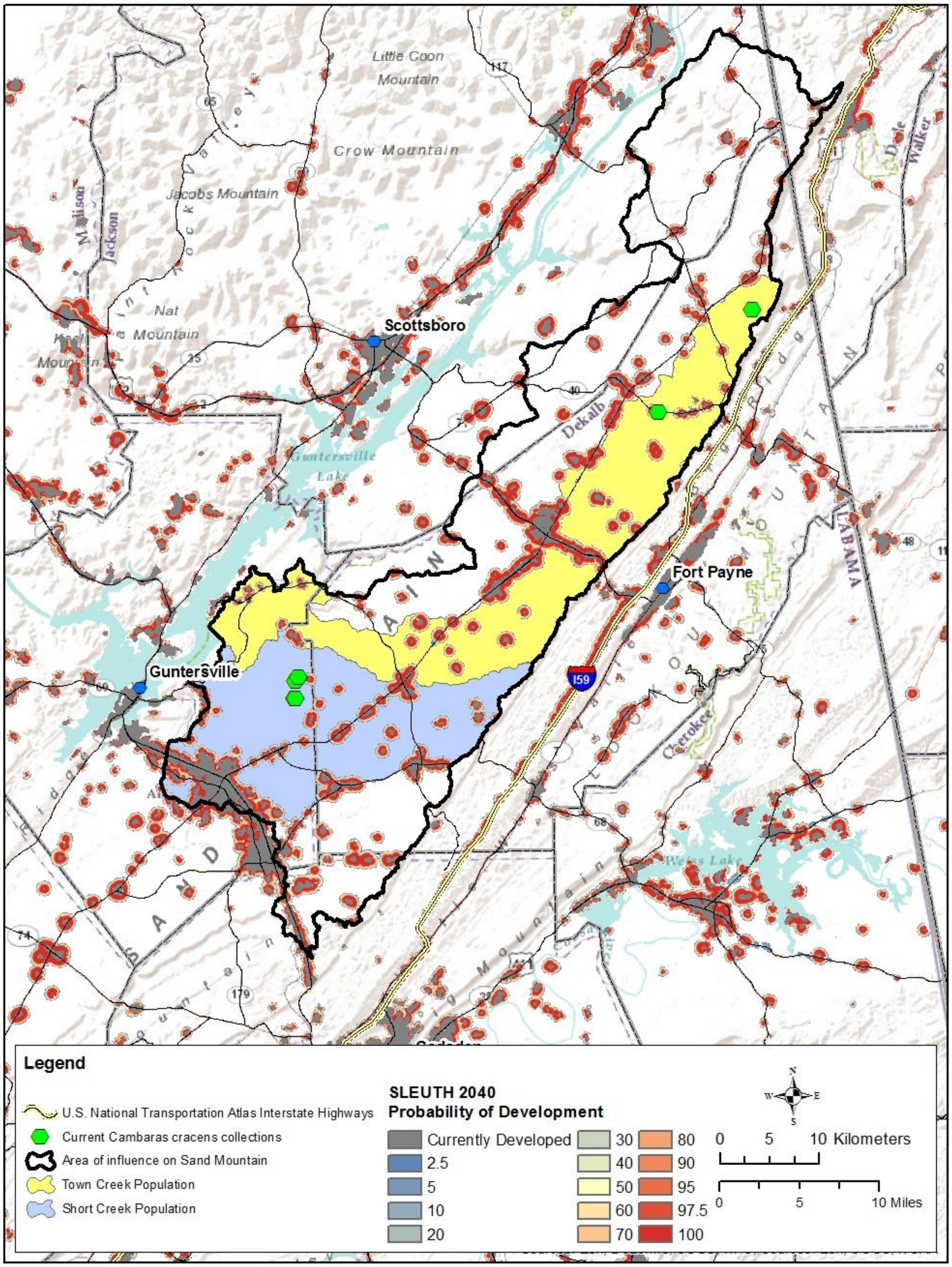

Figure 5-4. Projected urban land cover on and around Sand Mountain based on the SLEUTH model projected to 2040. Area of influence on Sand Mountain for the slenderclaw crayfish is outlined in black. The Short Creek population is highlighted in blue; the Town Creek population is highlighted in yellow.

5.2.3 Virile Crayfish Spread

As stated in Sections 3.3 and 4.3, the virile crayfish has an ecological advantage over native crayfishes (Clark and Lester 2005, p. 168) and has been documented at the slenderclaw crayfish type locality in Short Creek, and other sites within the range of slenderclaw crayfish. In Current Condition, we assessed virile crayfish presence or absence as a factor in the viability of the slenderclaw crayfish. In the future, we expected the virile crayfish to spread across the range of the slenderclaw crayfish at a natural rate of approximately 1640 ft/month (500 m/month) (Wong 2014, p. 4) from current known locations resulting in the loss of slenderclaw crayfish at those locations over time. This rate is more conservative than the documented approximate rate of spread at 124 miles (200 km) over 15 years (B. Williams pers. comm. 2018; Williams et al. 2011, entire). Using an approximate stream meter measurement in ArcGIS between known virile crayfish locations and current slenderclaw crayfish locations, and the approximate natural rate of spread (1640 ft/month (500 m/month)) (Wong 2014, p.4), we estimated virile crayfish occupation of known slenderclaw crayfish sites in both populations at time steps (2020, 2030, and 2040) and based on the following three scenarios (Section 5.3). The time steps begin in 2017, as this was the end of our current condition timeframe. Once virile crayfish reaches a new location, it is estimated that it would drive out native species within 10 years (C. Taylor pers. comm. 2018; B. Williams pers. comm. 2018; C. Williams pers. comm. 2018). For our analysis, we inferred that once virile crayfish reaches a known slenderclaw crayfish site, the slenderclaw crayfish would be eliminated at 10 years after initial virile crayfish presence. Bait transfer was also considered in Scenario 3 as an additional means of virile crayfish introduction, which would increase the rate of spread.

5.3 Scenarios

5.3.1 Scenario 1: Continued impact from land use on water quality; Low level of urban sprawl; Continued rate of virile crayfish spread

In Scenario 1, farming remains the predominant land use on Sand Mountain. Land use remains largely the same and, therefore, there will be a low level of urban sprawl. Current impacts to the landscape due to farming practices are expected to continue as evident in the water quality conditions. Low water events during the late summer to winter season will continue, and in some years, waterways may experience periodic prolonged drying periods by 2030, otherwise the model indicates precipitation is not likely to increase drying periods. Virile crayfish will spread further in the Short Creek population, specifically into the known (currently occupied) Shoal Creek sites, and will occupy the Town Creek population and its known slenderclaw crayfish sites, as time progresses.

<u>5.3.1.1 Population Resiliency Based on Scenario 1</u>

Given Scenario 1, both populations of slenderclaw crayfish will be in low condition overall by the year 2020 (Table 5-1). With a continued rate of virile crayfish spread, the non-native crayfish is expected to extend further into the Short Creek population, and occupy the most downstream site in Shoal Creek where the slenderclaw crayfish occurs. This Shoal Creek site is currently considered the most abundant slenderclaw crayfish location (n = 26) (Schuster 2017, unpublished data; Bearden et al. 2017, p. 17); therefore abundance of the population is expected to be reduced and will be in low condition. By 2020, the presence of virile crayfish was ranked very low condition. For the Town Creek population, the virile crayfish is expected to be captured in the lower reaches of Town Creek by 2020, and therefore, the presence of virile crayfish was ranked low. Since little change in land use was expected for both farming and urban areas, landscape level effects are expected to continue on trend, and therefore, the water quality condition factor was ranked low for both populations. Precipitation levels are not expected to impact water availability or water quality.

By the year 2030, the Short Creek population of the slenderclaw crayfish is expected to be extirpated and all currently known sites will be occupied by the virile crayfish (Table 5-1). The virile crayfish is expected to have spread into Shoal Creek and occupy known slenderclaw crayfish sites within the Short Creek population and, therefore, the presence of virile crayfish was ranked extirpated (indicating presence of virile crayfish in the population). In the Town Creek population, the virile crayfish will expand further into the population boundary, but is not expected to be within the currently known slenderclaw crayfish sites in Bengis and Town creeks. Therefore, the presence of virile crayfish was ranked low for the Town Creek population. Precipitation is expected to slightly decrease by the year 2030 and may add additional stress to the slenderclaw crayfish due to a prolonged dry season. This would be expected to negatively impact reproduction, as the dry season overlaps the period when the crayfish are reproductively active. Again, little change is expected to occur in the amount of farming and urban land use, and therefore water quality condition will likely remain in low condition.

By the year 2040, the Short Creek population of the slenderclaw crayfish is expected to be extirpated and all currently known sites will be occupied by the virile crayfish (Table 5-1). In the Town Creek population, the virile crayfish is expected to occupy the slenderclaw crayfish sites on Bengis and Town creeks, but the slenderclaw crayfish is still present though in very low abundance condition. Also, within the Town Creek population, a low level of urban growth was expected in and around the town of Rainsville. Thus, a slight decrease in farming is expected within this population. Precipitation levels are not expected to impact water availability or water quality by the year 2040. Water quality conditions are likely to remain in low condition and could support slenderclaw crayfish; however, the Short Creek population is expected to be extirpated while the Town Creek population will be in very low overall condition due to the virile crayfish.

Table 5-1. Estimated resiliency of the slenderclaw crayfish populations determined by assessing demographic and habitat factors under Scenario 1 at 2020, 2030, and 2040.

Population	Time Period	Abundance	Presence of Virile Crayfish*	Water Quality Condition	Overall Condition
Short Creek	2020	Low	Very Low	Low	Low
	2030	Extirpated	Extirpated	Low	Extirpated
	2040	Extirpated	Extirpated	Low	Extirpated
Town Creek	2020	Low	Low	Low	Low
	2030	Low	Low	Low	Low
	2040	Very Low	Very Low	Low	Very Low

*Lower condition does not reflect a lower presence of virile crayfish; this indicates resiliency of the slenderclaw crayfish populations in response to proximity of the virile crayfish.

5.3.2 Scenario 2: Additional measures to improve and protect water quality; Low level of urban sprawl; Slow rate spread of virile crayfish

In Scenario 2, farming remains the predominant land use on Sand Mountain. Land use remains largely the same and, thus, there will be a low level of urban sprawl. Best management practices (BMPs) and conservation programs improve conditions on farm land and water quality conditions gradually improve over time. Low water events during the late summer to winter season will continue, and these low water periods do not become longer than the current average. The virile crayfish will slowly spread further in the Short Creek population and will occupy the lower reaches of Town Creek mainstem in the Town Creek population as time progresses. Public education will occur about the spread of virile crayfish and its impacts to native crayfish, and therefore the spread of this non-native species via bait transfer will be reduced.

5.3.2.1 Population Resiliency Based on Scenario 2

Given Scenario 2, both populations of slenderclaw crayfish will be in low condition overall by the year 2020 (Table 5-2). Despite the slower rate of virile crayfish spread, the virile crayfish is still expected to spread further in the Short Creek population; thus presence of virile crayfish remained in very low condition, and the abundance factor was expected to remain in moderate condition at 2020. For the Town Creek population, the non-native crayfish is expected to be captured in the lower reaches of Town Creek by 2020, so the presence of virile crayfish and the abundance were ranked in low condition. Precipitation levels were not expected to impact low water cycles or water quality. Under this scenario, little change in land use was expected for both farming and urban areas. BMPs and conservation programs begin to make improvements to the landscape but have generally not increased the quality of the water by 2020, so the water quality condition factor was ranked low for both populations.

By the year 2030, both populations of slenderclaw crayfish will be in low condition overall. The virile crayfish is expected to have spread into Shoal Creek and occupy the known slenderclaw crayfish sites, but the slenderclaw is expected to remain, reducing the abundance category to low. The presence of virile crayfish remained in very low condition. There is an expected decline in the abundance of slenderclaw crayfish due to the virile crayfish spread, and thus, abundance factor was ranked low for the Short Creek population. The virile crayfish will have further expanded into the Town Creek population and the presence of virile crayfish was ranked in low condition. Precipitation levels are not expected to impact low water cycles or water quality. Again, little change was expected to occur in the amount of farming and urban land use, and with the implementation of BMPs, water quality has begun to improve. Water quality condition was ranked moderate for the Short Creek population and low for the Town Creek population.

By the year 2040, the Short Creek population is expected to be extirpated and the Town Creek population was ranked in low condition. All currently known sites within the Short Creek population will be occupied by virile crayfish. In the Town Creek population, the virile crayfish has recently spread into the currently known slenderclaw crayfish sites, reducing the abundance, resulting in very low condition for that factor and the presence of virile crayfish factor was ranked low. Precipitation levels are not expected to impact low water cycles or water quality. Within the Town Creek population, a low level of urban growth is expected in and around the town of Rainsville. Thus, there was a slight decrease in farming and slight increase in urban areas expected. However, water quality conditions are expected to improve further. Despite improved water quality conditions for the slenderclaw crayfish and aquatic macroinvertebrates (the likely food source for juvenile slenderclaw crayfish), the presence of virile crayfish is expected to still cause the extirpation of the slenderclaw crayfish in the Short Creek population and keep the Town Creek population in low condition.

Table 5-2. Estimated resiliency of the slenderclaw crayfish populations determined by assessing demographic and habitat factors under Scenario 2 at 2020, 2030, and 2040.

Population	Time Period	Abundance	Presence of Virile Crayfish*	Water Quality Condition	Overall Condition
Short Creek	2020	Moderate	Very Low	Low	Low
	2030	Low	Very Low	Moderate	Low
	2040	Extirpated	Extirpated	Moderate	Extirpated
Town Creek	2020	Low	Low	Low	Low
	2030	Low	Low	Low	Low
	2040	Very Low	Low	Moderate	Low

*Lower condition does not reflect a lower presence of virile crayfish; this indicates resiliency of the slenderclaw crayfish populations in response to proximity of the virile crayfish.

5.3.3 Scenario 3: Reductions in water quality through poor practices; Moderate to high level of urban sprawl; Extended low water periods; Fast rate of spread for virile crayfish

In Scenario 3, farming remains the predominant land use on Sand Mountain with a moderate to high level of urban sprawl occurring. Land management practices will result in degraded water quality and negative impacts to the macroinvertebrate community. Longer low water events during the late summer to winter season are predicted and will impact critical life stages such as the reproductive stage of the slenderclaw crayfish. Virile crayfish will rapidly spread naturally and via bait transfer further in the Short Creek population, occupying all known slenderclaw crayfish sites, as well as expanding into the Town Creek population and the known slenderclaw crayfish sites there.

5.3.3.1 Population Resiliency Based on Scenario 3

Given Scenario 3, the Short Creek population will be in very low condition overall and the Town Creek population will be in low condition overall by 2020. With the faster rate of virile crayfish spread, the non-native crayfish is expected to be present at currently known locations of slenderclaw crayfish in Shoal Creek by 2020 and, therefore, the presence of virile crayfish factor was ranked very low condition for the Short Creek population. Due to the virile crayfish spread, we would expect a reduction in the abundance as well, so this factor was ranked very low for the Short Creek population. For the Town Creek population, the virile crayfish is expected to be captured in the lower reaches of Town Creek and continue spreading further into the watershed by 2020; therefore, the presence of virile crayfish was ranked in low condition. Future precipitation levels are not expected to impact low water cycles or water quality. Little change in land use is expected for both farming and urban areas, but the lack of conservation practices on the landscape is expected to reduce water quality, and so, the water quality condition remained in low condition for both populations.

By the year 2030, the Short Creek population is expected to be extirpated due to the rapid spread of virile crayfish with the slenderclaw crayfish no longer occupying the Shoal Creek sites. The Town Creek population will be in very low overall condition since the virile crayfish was expected to drive out the slenderclaw crayfish at the Bengis Creek site, reducing the rankings for the presence of virile crayfish and abundance conditions to very low. Precipitation levels are expected to have a slight impact on low water cycles and water quality, lowering dissolved oxygen levels and increasing eutrophic conditions. Prolonged low water periods would have a negative impact to the reproductive success of the slenderclaw crayfish for a short time, though precipitation is expected to increase after 2030. Again, little change in land use is expected, but a further decline in water quality condition is expected to occur due to land management practices and lack of conservation practices and, therefore, the water quality condition remained in low condition for both populations.

By the year 2040, the Short Creek and Town Creek populations are expected to be extirpated, and all currently known sites will be occupied by the virile crayfish. Also, within the Town Creek population, a moderate to high level of urban growth is expected in around the town of Rainsville and would potentially further limit the habitat available for the slenderclaw crayfish. Thus, a slight decrease in farming is expected within this population. Water quality conditions are expected to experience further decline and remain in low condition for both populations. Precipitation levels are not expected to impact low water cycles or water quality by 2040 as a slight increase in overall precipitation is expected to occur.

Table 5-3. Estimated resiliency of the slenderclaw crayfish populations determined by assessing demographic and habitat factors under Scenario 3 at 2020, 2030, and 2040.

Population	**Time Period**	**Abundance**	**Presence of Virile Crayfish***	**Water Quality Condition**	**Overall Condition**
Short Creek	2020	Very Low	Very Low	Low	Very Low
	2030	Extirpated	Extirpated	Low	Extirpated
	2040	Extirpated	Extirpated	Low	Extirpated
Town Creek	2020	Low	Low	Low	Low
	2030	Very Low	Very Low	Low	Very Low
	2040	Extirpated	Extirpated	Low	Extirpated

*Lower condition does not reflect a lower presence of virile crayfish; this indicates resiliency of the slenderclaw crayfish populations in response to proximity of the virile crayfish.

5.4 Summary of Future Conditions and Viability based on Resiliency, Representation, and Redundancy

5.4.1 Future Population Resiliency

In terms of resiliency, the Short Creek population remains in low condition under two of the three scenarios by the year 2020 (Table 5-4). The Town Creek population remains in low condition under all three scenarios by the year 2020. By the year 2030, the Short Creek population has become extirpated under two of the three scenarios (Table 5-5); under Scenario 1 (continued impacts on water quality and rate of virile crayfish spread) and under Scenario 3 (reductions in water quality and fast rate of virile crayfish spread), the Short Creek population will be extirpated by 2030. The Town Creek population will remain in low condition under all scenarios except for Scenario 3; this population will be reduced to very low condition by 2030. By the year 2040, the Short Creek population of slenderclaw crayfish will become extirpated under the three scenarios (Table 5-6). The Town Creek population will remain in low condition under Scenario 2 by the year 2040, but the population will be reduced to very low condition under Scenario 1. In addition, we expect the Town Creek population to become extirpated under Scenario 3 by the year 2040 (Table 5-6).

In the Short Creek population, the virile crayfish was expected to impact the condition of the slenderclaw crayfish at a faster rate than the Town Creek population, because the virile crayfish currently occupies four known sites in the Short Creek population and is in near proximity to the known locations of the slenderclaw crayfish. The slenderclaw crayfish site that is nearest to the currently known virile crayfish is currently the most abundant slenderclaw crayfish location (n = 26) (Schuster 2017, unpublished data; Bearden et al. 2017), therefore resiliency is lowered for the entire population once the virile crayfish reaches this site. In addition, for the Short Creek population, all known slenderclaw crayfish sites are in a single tributary. The two currently known locations of the slenderclaw crayfish in the Town Creek population occur in two streams, and the virile crayfish is not currently documented within the population boundary. However, only four individuals have been captured in the Town Creek population since 2009. Therefore, due to the few individuals collected, there is uncertainty about the reproductive success of this population into the future. As a note, reproductive success was not accessed in our future condition analysis. Over time, water quality may improve on Sand Mountain; however, the presence of virile crayfish is a more powerful driver in the future condition of the slenderclaw crayfish. Under all scenarios, virile crayfish is expected to move across the range of slenderclaw crayfish at a rate of approximately 1640 ft/month (500 m/month) from known locations (Guntersville Lake, Drum Creek, and Shoal Creek) resulting in a gradual replacement of native species with virile crayfish (Wong 2014, p. 4). The effect of other factors impacting the species will be reducing available habitat through time. In addition, the spread of virile crayfish and likely expansion of Rainsville, Alabama will reduce the habitat available to the slenderclaw crayfish, even if habitat quality improves. Overall, given the reduced abundance and presence of virile crayfish, the slenderclaw crayfish populations will have very low resiliency or will be extirpated in the future.

Table 5-4. Summary of current and future resiliency of the slenderclaw crayfish populations, Short Creek and Town Creek. Time period is 2020, 2030, and 2040 for the three future scenarios.

Population	Time Period	Current	Scenario 1	Scenario 2	Scenario 3
Short Creek	Current	Low			
	2020		Low	Low	Very Low
	2030		Extirpated	Low	Extirpated
	2040		Extirpated	Extirpated	Extirpated
Town Creek	Current	Low			
	2020		Low	Low	Low
	2030		Low	Low	Very Low
	2040		Very Low	Low	Extirpated

5.4.2 Future Species Representation

In Scenarios 1 and 2, the slenderclaw crayfish may persist by the year 2040, and this is with one population (Town Creek) with low to very low resiliency; the Short Creek population will become extirpated. In Scenario 3, both populations of the slenderclaw crayfish will be extirpated by 2040. The Short Creek population occurs in the large boulder, wider stream habitat type and, therefore, this habitat type will be lost, reducing the habitat variability of the slenderclaw crayfish. In addition, the morphological variation of the species occurred in the Short Creek population. Overall, there will be a reduction in the occupied range of the species through the loss of the Short Creek population and at a minimum, its range within the Town Creek population will be highly restricted to the headwaters due to the expansion of virile crayfish and urban areas. The future representation of this species is reduced under all scenarios and time periods.

5.4.3 Future Species Redundancy

The slenderclaw crayfish exhibits low natural redundancy given its narrow range and, in the future, the presence of virile crayfish is expected to reduce redundancy further. Within both populations of the slenderclaw crayfish, there are historical sites that are currently considered extirpated; in the future, additional sites (and possibly both populations) are expected to become extirpated. The recolonization of sites (or one of the populations) following a catastrophic event would be very difficult given the loss of additional sites (and one or both populations) and reduced available habitat to the remaining population due to virile crayfish expansion, urban growth, and Guntersville Lake.

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